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MAISTER PETER LOWE.

1550?—1610.

MASTER PETER LOWE is known in a double capacity. He was the founder of the Faculty of Physicians and Surgeons of Glasgow, and was the writer of a text-book on surgery which ran through four editions between 1597 and 1654. In point of time he occupies a position between the Elizabethan surgeons and John Woodall, the Caroline interpreter of surgery. The Elizabethan surgeons were purely English; Woodall was trained in Russia and Germany; Lowe was tinctured with French surgery, at a time when the feud between the gentlemen of the long robe or the physicians, and those of the short robe or the barbers, was in its most acute stage.

Little is known of the personal history of Peter Lowe. He was born about 1550, perhaps at Errol, and he was certainly a Scotsman. He left his native country as a boy about 1565, for he gives the following account of his career, the dates being somewhat doubtful: "I impart to you my labours and experiments by me practised and dayly put in use to the great comfort, ease and delight of such as have had occasion to use my help in France, Flaunders and elsewhere, the space of 22 years; thereafter being Chirurgian Major to the Spanish regiments at Paris 2 years; next following the French King my Master in the wars 6 years, where I made commodity to practise all points and operations of Chirurgery." The mention of the Spanish regiment fixes one date, for the Spaniards sent help to the Catholic League organized by the Guise party, and helped them to hold Paris against Henry IV in 1588–90.

In speaking of aneurysm he also gives a date, for he says, "I remember in Paris in anno 1590 there happened such a disease to a valiaunt Captaine (my great friend Captaine Bayle who was one of the chiefest captaines amongst the Spaniards at Paris) on the right side of his cragge, for the which I, a chirurgion major to the regiment, was sent for and found it to bee an Aneurisme so not to bee touched; of the which opinion was my good friend Andrew Scot, who was a great practitioner at Paris for the time and wel exercised in the art of Chyrurgery. We did ordaine remedies to let the encrease of it, which receipt being sent to the Apothecary, who before had seene the saide Captaine, did thinke it no meete medicine for an Aposthume (as he tearmed it) so presently he sent for an ignorant Barbor like unto himselfe, who did sweare unto the Captaine that they had salves and charmes for all sores, so without further tryall did open it with a Launcet to avoyde the matter (as they thought) which being done the spirit and bloud came forth with such violence that the Captaine dyed in a fewe howers after."

Lowe appears to have graduated in surgery at Paris, because he describes himself as "Doctor in the Facultie of Chirurgerie in Paris." The statement

is slightly inaccurate, because the Surgeons' Company only gave a Mastership, which corresponded to the Doctorate in Physic granted by the University.

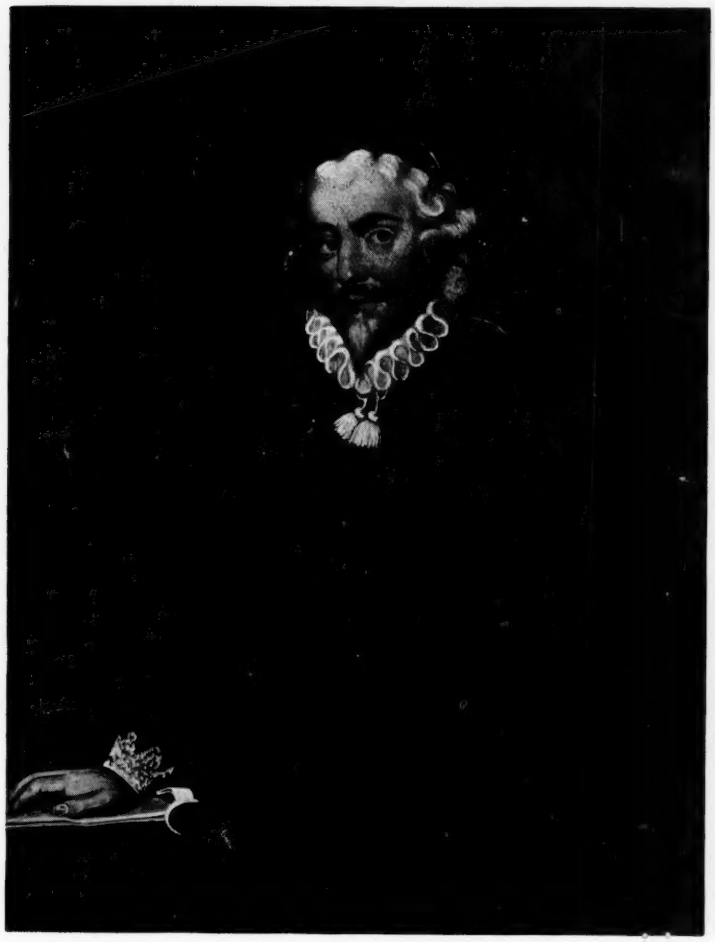
In 1596 his name is said to appear in some manuscript registers at Orleans, and it was perhaps with the desire to mark his connection with the College of that city that he calls himself "Arellian." In 1596 he was in London and had made the acquaintance of the principal surgeons, for he induced William Clowes to write a preface to his book, and George Baker, " one of his Majesties chiefe Chirurgions in ordinarie," to recommend it—in verses whose quality can be judged by the concluding lines :

> Then Doctor Lowe thy lamp doth give such light
> That everyone to vertue fame doth yield
> Passe on with prayse through every soyle and coast
> Where Lowe is knowne he shall be honoured most.

In 1596 he published *An Easie, Certaine and Perfect Method to Cure and Prevent the Spanish Sickness*, a small pamphlet of forty-two pages in quarto, printed at London by James Roberts, the well-known printer of the Shakespeare quartos. The pamphlet deals with the symptoms and treatment of syphilis, the treatment being chiefly by means of an electuary the composition of which is not disclosed. *The Whole Art of Chirurgerie* was published in London by Thomas Purfoot in 1597. A second edition appeared posthumously in 1612, much enlarged and with illustrations taken from Paré and Guillemau. The third and fourth editions, issued in 1634 and 1654, are mere reprints of the second edition. Bound up with each edition, and with a separate title page, but without pagination, is *The Presages of Divine Hippocrates*, dedicated to "Robert Lord Sampile, Sheriffe of Renfrew," in the 1597 edition, and to "The Reverend Father in God, John Archbishop of Glasgow," in the later editions. The *Presages* is translated from the French version published by John Canape at Lyons in 1552, which was itself translated from the Latin one made by Rabelais.

The following extracts from *The Whole Art of Chirurgerie* show the general character of the teaching. The matter is clearly expressed, and the teaching is definite; for the most part it was the outcome of personal experience.

Amputation.—The difficulties which the older surgeons had in dealing with bleeding are well shown by the following account of an amputation for gangrene: "The friends being first advertised of the danger, because that often times death ensueth either for fluxe of blood, feare, faintness and swooning after it is done. Likewise there happeneth often fevers, reveries, extreme dolours, convulsions, cold sweats and often times sudden death: for which the parents and friends should be foreseen of the danger which may happen. The place of amputation being remarked you shall have two men to hold and attend upon the patient, then the chirurgion shall command the sicke to bend out and extend that member to the end the skin, veins, arteries and nerves may be more lengthened and, after the amputation, may be more apparent to be knit or cauterised. That being done, the chirurgion shall plucke up the skinne and muscles as much as he can, thereafter he shall take a strong ribbon and bind the member fast two inches above where the amputation shall be.



PETER LOWE

The usage of the ribbon or band is divers. First it holdeth the member hard and fast so that the instrument or incision knife may cut more surely. Secondly that the feeling of the whole parts may be stupefied and rendered insensible. Thirdly that the flux of blood may be stayed. Fourthly it holdeth up the skin and muscles which must cover the bone after it be cut and so it maketh it more easy to heal. The bandage then being thus made we cut the flesh with a razor or incising knife which must be somewhat crooked to the form of an hook or half moon. The flesh then being cut to the bone, the said bone must be diligently rubbed and scraped with the back of the said knife which back must be made purposely for that effect to the end the periost which covereth the bone may be less painful in cutting of the bone: otherwise it teareth and riveth with the same, so causing great dolour: also letteth the cutting, although the bone have no feeling of itself. This being done you must saw the bone with a sharp saw: then loose the ligature, draw down the skin and cover the bone in all the parts, and then, if there be great putrefaction, let it bleed a little, for that dischargeth the part and so is less subject to inflammation. Then one of the Assisters shall put the extremities of his fingers on the great vein and artiers to stay them from bleeding, till the chirurgion either knit or cauters, the one after another as he shall think expedient. But where there is putrefaction we stay the flux of blood by cauters actual, and where there is no putrefaction, malignity, nor humor venomous we use the ligator. The cauter or actual fire stayeth bleeding, consumeth and draweth into it the virulency and malignity of the humour which is in that part and in that point it is more sure and better than knitting. In knitting we lose much blood and by drawing the veins with the back Decurbin (forceps), or other instrument they do break. Also being knit do often unloose, so that I find the fire more expedient. It hath the virtue to dry and corroborate; being made red hot, then we take either of the cauteries and apply on the vein, one after another, continuing them a certain space till the seal be made: taking heed always not to burn overmuch of the vein. In amputation without putrefaction I find the ligator reasonable sure providing it be quickly done. To do it, first thou shalt cause the assister to hold his fingers on the veins letting one loose, on the which thou shalt take hold with the back Decurbin, taking a little of the flesh or muscles with it: then put through a needle with a strong thread, knit with a double knot, tying a little of the flesh with the vein which will make it hold the better: but if it slip as oft it happeneth, you shall first put through the needle in the utter skin, an inch above the wound, near to the side of the vein, cause it to come forth by the other side of the vein, yet higher than the orifice of the vein. Then pull out your needle an inch from the part where it went in: then put a piece of cloth in two doubles betwixt the two threads, then tie it hard, to the end the knot enter not in the skin. This way and form must be used for the rest of the veins."

Cataract.—The operation for cataract is described with equal clearness, and is the more interesting because it is written by a surgeon at a time when couching was usually performed by an itinerant quack: "The cataract being ripe: the body must be purged and prepared by medicines, sirups and bleeding if need require, then the sick shall rest a day or two, and we come to the

manual operation which shall be meetest in the morning about eight or nine of the clock: the patient being weak, give him a toast of bread with small wine or clean Ale, thereafter set him on a form or stool in some light place, in such sort that his face be directly before the chirurgion; then one must stand behind him to hold his head fast and stable and another must hold up his eyelid with his thumb and finger that the chirurgion may see the better: that being done, the chyrurgeon shall sit on the same form, or some other seat somewhat higher, directly against the sick and so near that the hands of the sick may rest upon the chyrurgeon's thighs, then the chirurgeon shall stab the needle often in some cloth to make it sound and hot. It must neither be rough nor cold to the membranes of the eye: then the operator or some young child who hath a sweet breath shall chew cinnamon, ginger, cloves or fennel and spit it out and breath three or four times in the eye of the sick, it being open and that prepareth the eye and maketh the cataract more thin: then he shall cause the sick to close the whole eye and hold it closed, for if it move the sore moveth also and hindreth greatly the operation. Next the chyrurgion shall cause the patient to open the sore eye and turn it towards the nose if it be the right eye, the chyrurgion shall with his finger and thumb of the wrong hand upon the eye, hold it stable and firm, which being done, the chyrurgion shall thrust in the needle which must be sharp pointed a little lower than the middest of the eye overthwart the membranes named conjunctiva and cornea, taking allways heed not to offend the veins of the conjunctive, let it go towards the side of the little corner which is near the temples, directly to the foreside of the cataract not advancing over farre then by little and little turn the needle gently until such time as you couch the cataract to the lowest part of the eye and being there hold it down a pretty space, then retire the needle the way that it went in, if it doth rise again as often chanceth, the dolour being ceased, pass the needle as before, but not at the same passage."

In 1598 Lowe was in Glasgow, and had come under the censure of the Church for some breach of discipline. He was condemned to make his repentance at 'the Pillar' on three Sundays and to pay a fine. His next record is more reputable, for on the penultimate day of November, 1599, a Charter was granted by King James VI. of Scotland to "Maister Peter Low our Chirurgiane with the assistance of Mr. Robert Hamiltone professoure of Medicine," giving them power to call before them within the burgh of Glasgow all persons professing or using the art of surgery. The surgeons were to be examined and licensed; the physicians were called upon to produce their university testamurs; apothecaries were controlled; and the very existence of barbers was ignored. The Charter thus followed closely upon the lines of contemporary medical teaching in France.

In July, 1601, Maister Peter Lowe accompanied the Duke of Lennox on an embassy to Paris, and the work of the Faculty created by the Charter did not begin until 1602. Lowe never filled the office of President, but contented himself with the dignified but troublesome post of 'Quartermaster' or Treasurer.

He was twice married, and had a son, John, by his first wife, and a daughter, Christiane, by his second. He died Aug. 5, 1610, leaving a sum

of £5562 8s. 8d. Scots, or about £463 English money, equal to nearly £4600 at the present value. It is noteworthy that his capital was lent out at interest to various Scottish noblemen and gentlemen. He is buried in the churchyard of Glasgow Cathedral, where his tomb with its inscription is a prominent and well-known object. The epitaph seems to give some picture of the man. It runs—

Stay Passenger and View this stone
For under it lyis such a one
Who cuired many whil he lieved
Soe gracious he noe man grieved
Yea when his physicke force oft failed
His plesant purpose then prevailed
For of his God he got the grace
To live in mirth and die in peace
Heavin hes his soul, his corps this stone
Sigh, passinger, and soe be gone.

GENERAL PATHOLOGY OF ACUTE BACILLARY GANGRENE ARISING IN GUNSHOT INJURIES OF MUSCLE.

By Captain E. F. BASHFORD, R.A.M.C.

This paper had its inception in more modest inquiries, undertaken with Captain Hartley, on the one hand into the normal processes of healing in muscle, with some of the features of which I had become familiar during years of attention to the processes taking place at the site of the inoculation of cancer, where muscle is frequently involved; and on the other hand, into the alterations in the normal process arising from the infection of gunshot injuries. These inquiries forced me almost imperceptibly at first, but nevertheless inevitably, to study 'gas gangrene,' as it is commonly called; and gradually the number of new facts extended the scope of the inquiry, till it has come to embrace the whole subject of what I prefer to call 'anaerobic,' or better, 'acute bacillary gangrene,' or 'war gangrene,' for reasons which will become apparent to all who read this paper. The number of fresh questions opened up is large, and many others are in a position to take them up more adequately than would be the case were I to attempt to cope with them all after a further lapse of time. I had only been engaged on the work a fortnight when Major Sidney Rowland joined me, full of ideas of his own on the subject of wounds, and we have been associated in their study ever since.

I. HISTOLOGY OF BACILLARY INVASION OF MUSCLE.

The examples given below illustrate, although only in rough outline, some essential features of the bacillary invasion of 'gunshot' injuries of muscles. They have been selected from a great number of cases because of the clearness with which they bring out one or other of several consequences of gunshot injuries. Histological investigations have well-defined limitations, not the least so in investigating bacteriological problems. Since, however, the histological study of wounds with a view to elucidating problems of surgery has largely concerned itself in the past with observation of sterile and incised wounds, there is a wide field in which accurate knowledge may be acquired of the processes in wounds where there has been massive destruction or removal of tissue, and which have been heavily infected with bacilli by 'gunshot' injuries. In the absence of accurate knowledge of what is actually taking place in the neighbourhood of the site of injury, and also of the changes which may be accompaniments in the body as a whole, lines of treatment—however beneficial some may appear to be—are merely shots in the dark, and some of them may unintentionally aggravate evils arising from the infected wound, and exercise harmful effects either locally or constitutionally.

The great preponderance of gunshot wounds involve the muscles, and in a previous paper evidence has been adduced that the only injury to muscles discoverable by histological study is immediate in its onset, and sharply

circumscribed. Around the missile track is produced a zone of disintegrated muscle, a freshly-made 'beef emulsion,' which is sharply marked off from the adjacent living fibres, though the interspaces between the bundles and fibres open into this ideal culture medium (*Fig.* 297).

It may be recalled that there are no lymphatics in muscle, except in the outer connective-tissue sheaths and in the tendinous origins and insertions. The muscle, i.e., the areolar tissue of innumerable subdivisions of the endomysium, forms one huge lymph space, in which equally innumerable muscle fibres and capillaries lie embedded. It is necessary to consider the long muscles of the limbs separately from the segmental muscles of the trunk, because in the former the lymph space will be opened into, and the mass of muscle which will suffer the secondary effects of any interference with its blood-supply is very much greater than in the latter.

FIG. 297.—The muscle fibres at the top of the figure have been immediately killed by the violence of the missile, and are sharply delimited from the living muscle fibres, some of which show a proliferation of the nuclei of the sarcolemma. At the bottom, limit of surgical incision into healthy muscle. Twenty hours after wound.

Segmental Muscles.—A wound of the rectus abdominis came under the observation of Dr. Acker, to whom I am indebted for the specimen, which he removed five days after the injury. A piece of shrapnel weighing 28 grms. entered the chest wall below the left nipple, and passing down over the ribs, made a track into the upper part of the abdominal wall without entering the cavity. The missile was found lying in the rectus abdominis, embedded in seven or eight square inches of greatcoat and some portions of tunic and shirt. The wound, the condition of which the surgeons regarded as being typical of gas gangrene, was simply laid open and the gangrenous zone excised. It was then washed with sterile distilled water, and thereafter passed uneventfully to complete healing. The shrapnel was placed in bouillon and incubated anaerobically. A portion of the greatcoat was placed in glucose-agar, and

another portion in nutrient bouillon in a Buchner tube. A third portion was placed in Zenker's fluid, and subsequently cut into sections. By all methods the presence of an extraordinary variety of bacteria and cocci was ascertained, similar to those mentioned below in the description of the injured muscle. The variety of organisms speedily diminished in subcultures, and after three and four, only a growth of cocci was obtained.

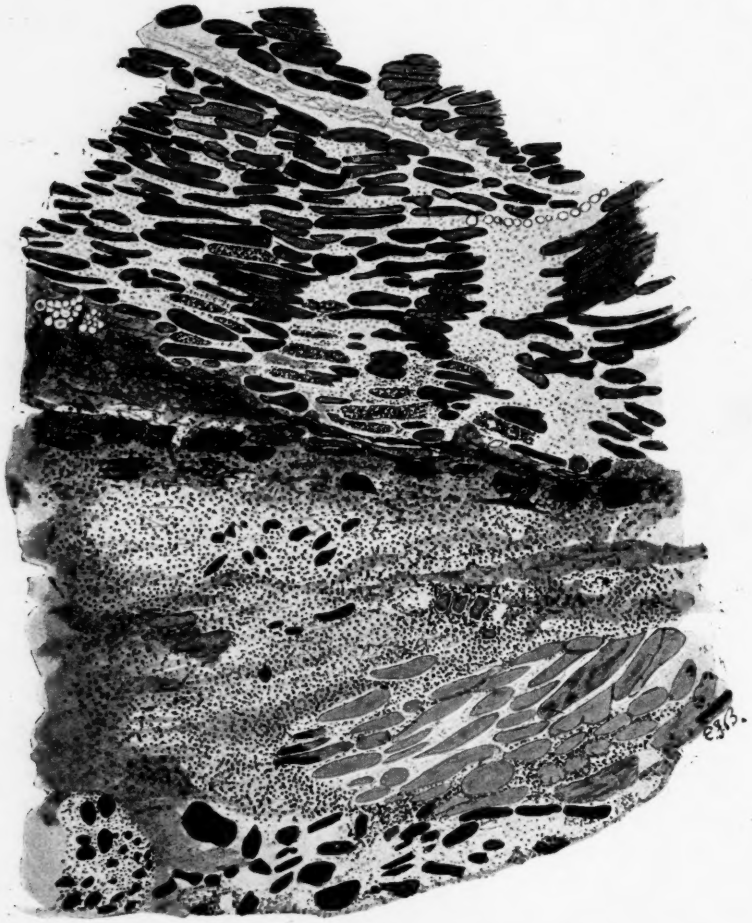


FIG. 298.—Limitation of gas gangrene in a segmental muscle.—Three segments of rectus abdominis. Five days after wounding, 28 grams of shrapnel, together with portions of great coat, tunic, and shirt were removed. They lay on the lower injured segment, which is crowded with organisms and leucocytes. An injured septum separates it from the middle segment, which contains muscle fibrils showing abortive attempts at regeneration—the muscle fibres being widely separated by an exudate containing some leucocytes. The third segment shows normal muscle bundles, which are also seen at the top right-hand corner of the middle segment. The muscle fibres at the foot of the figure are structureless and stain darkly (killed by violence). Near them are fibres showing typical ground-glass appearance as produced by bacillary products.

The histological appearances of a portion of the excised segmental muscle, which was cut into hundreds of sections, mounted in series, and examined from end to end, are shown in *Fig.* 298. It comprises three segments. In the

first segment, at the foot of the figure, the muscle fibres are shown on which the projectile lay with its cloth coverings. These muscle fibres are those which were immediately killed; they are darkly stained and devoid of all structure. Their nature can only be inferred from the anatomical arrangement. Above them there is another group of muscle fibres staining more faintly and having an appearance like ground glass. They are equally devoid of all structure, although they have retained the anatomical arrangement better. They also may have been killed immediately, for they show no signs of any regeneration, such as would have resulted in a breaking up of the sarcous substance, no signs even of a proliferation of the sarcolemma nuclei having taken place. On the other hand they are identical in appearance with muscle fibres which, while remote from a wound, are embedded in a massive bacterial infection, and this is more probably the sole cause of their peculiar appearance (compare *Figs.* 298 and 307). The rest of this segment is made up of muscle débris and old organized clot, with a vast accumulation of leucocytes.

An intramuscular septum much injured by the missile, and filled with old hæmorrhage, intervenes between the first and second segments. The muscle fibres in the second segment are widely separated by an exudate crowded with leucocytes. In some places the leucocytes are so densely packed that the capillaries between the fibres are obliterated; in other places the capillaries have ruptured, and hæmorrhage has mingled with the exudate. The leucocytic infiltration diminishes in intensity as the third segment is approached. In the lower portion of the second segment many of the muscle fibres have attempted to pass into the stage of regeneration, as described for the zone adjoining those suffering immediate death, and indicated in *Fig.* 297, and also in *Figs.* 251 and 253 in an earlier paper.[1] The sarcous substance is broken up by proliferating sarcolemma cells, but the regeneration has been interfered with, and these fibres are also crowded with leucocytes, from which the sarcolemma nuclei are often indistinguishable owing to fragmentation. The majority of the fibres, however, show little departure from normal, and have retained their striations. A portion of the second segment shows, at the top right-hand corner, muscle bundles which are quite normal.

The third segment shows no other disturbance than that which was due to the knife of the surgeon. The intramuscular septum between the second and third segment shows little change (compare also *Fig.* 252, p. 452, in the earlier paper) beyond slight hæmorrhages and possibly an increased cellularity. The three segments may therefore be taken roughly as (1) injured, (2) reacting, (3) normal.

In the injured segment, staining of smears by Gram, Saathof, or methylene-blue, showed the presence of a most extraordinary number and variety of organisms (for number compare *Fig.* 307, which however is a pure growth). In keeping with the surgeon's opinion on the condition of the wound, there are present organisms resembling the *B. perfringens*, and also the *B. œdematis maligni*;* but they may be Hibler's bacillus or any of many others. As a

* The presence of this organism in wounds has not attracted so much attention as *B. perfringens*. It occurs quite frequently in my experience, and Miss Robertson, of the Lister Institute, isolated it nine times out of twelve in material sent to the Lister Institute by Major Rowland.

matter of fact it is as valueless as it would be inaccurate to attempt to record the surprising variety of long, short, fine, curved, thick, and thin bacilli, large and small cocci, or bacteria with terminal spores, subterminal spores, or medial spores. As mentioned above, the attempt to maintain this diversity in culture for experimental purposes failed. What is important to record is that in sections this great variety is at its maximum *among* the dead muscle fibres, not *in* them, and most of the fibres have persisted without extensive bacterial invasion, or without being invaded at all. Here and there a colony of one type of bacillus is met with, or a muscle fibre—usually greatly disintegrated—bristles with bacteria, like a china pig on which grass seed has been sown ; but these are exceptional. The bacilli are not essentially 'muscle feeders,' as the phrase goes, but live in the lymph spaces which represent the endomysium, and in the ' beef emulsion.' The variety is less in the clot, with its multitude of leucocytes. Cocci and a small bacillus preponderate near the injured septum, and here also many organisms are observed inside leucocytes, whereas they are not so included in the area of massive mixed infection or maximal bacillary growth (*Figs.* 298, 303, 304, 305, and 306). No organisms at all are observed beyond the first injured septum (with the doubtful exception of a few granules which may be débris, but may or may not be a few Gram-positive cocci), but the histological method of itself becomes unreliable at this point.

The careful study of the continuous series of sections of the specimen, and others like it from the segmental muscles of the back, has yielded no example in which the appearances departed essentially from the description given above. It may therefore be regarded as a typical infected gunshot wound of a segmental muscle. The bacterial invasion ceases or is effectively stayed where the circulation is maintained unimpaired ; but the influence of the bacterial products has extended into this zone, and has there interfered with the regenerative process in muscle ; this has aborted. The natural anatomical and physiological arrangements have sufficed to handicap the bacterial invasion sufficiently for surgery to intervene successfully.

Long Muscles.—A segmental muscle gives in brief compass a picture of what takes place in long muscles, but in the former there is a more marked delimitation of the several processes. In a long muscle, the various stages of tissue injury and bacterial invasion may pass rapidly from one to another throughout a great length of tissue ; the bacterial invasion, acquiring increased magnitude with every step, comes to involve not only single muscles, but groups, and even the entire limb.

After infection has been fully established in a long muscle, the intensity of the processes resulting therefrom can often be well followed from the central fibres towards the sheath, which frequently remains uninfected, but may be the chief seat of the spread of the bacilli. The septa between muscles, the connective tissue surrounding veins, or such structures as Hunter's canal, may be the paths of extension.

1. *The Portion Cut Off from the Blood-Supply.*—In an injury to a long muscle, the portion distal to the wound must be considered separately from the proximal portion which still retains its blood-supply. The gracilis femoris may be taken as exemplifying what has been found in other long muscles. It receives its arterial supply high up from the obturator artery, and an injury is

liable to cut off a considerable length of muscle from the blood-supply. Captain Morrison supplied such a specimen of the gracilis femoris. It was over six inches long, and included the muscular insertion; unfortunately the injured edge of the upper portion was not preserved, because, showing nothing of note, it was not excised extensively.*

FIG. 299.

FIG 300.

FIG. 301.

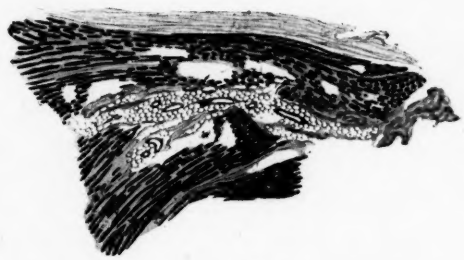


FIG. 302.

FIGS. 299, 300, 301, 302.—Destruction by bacillary invasion of a portion of a long muscle cut off from the blood-supply.—Four segments of the gracilis femoris, showing the appearance from the wound down to the insertion, the distribution of bubbles of gas in the muscle fibres and sheath, and disorganization of the muscle bundles throughout, except at the insertion. A segment between *Figs.* 301 and 302 has been omitted.

The muscle after thorough fixation in several changes of Zenker's fluid, had shortened considerably, and was cut into five blocks each about 2 to 3 cm. in length. After embedding, a large number of serial sections was cut from each block, so as to obtain the sheath and a breadth of 1, 2, or more cm.

* The femoral artery had been injured and was thrombosed at this time, but not the femoral vein. Three days later the patient had a bad secondary hæmorrhage, and some thrombosed veins (not the femoral) were removed. The patient ultimately recovered.

of the muscle; in some cases it was possible to obtain sections right across the muscle from sheath to sheath. The appearances of the muscle were then studied from the wounded margin to the insertion, the general appearances being as indicated in *Figs.* 299, 300, 301, and 302 for four out of the five blocks of muscle. Nearest the injury there is a zone of dead fibres—dark-staining fibres—embedded in clot which is disorganized by a varied and prolific bacterial growth. Beyond them there is a zone of fibres having a ground-glass appearance, as in *Figs.* 298 and 307; and beyond these again the fibres, while often greatly fragmented, depart most markedly from the normal in being widely separated and in having often lost their cross-striations (*Figs.*

FIG. 303.—Less advanced infection.—Bacilli spreading five and a half inches from wound, between muscle fibrils and long capillaries or being taken up by leucocytes. The bacilli are applied to the sarcolemma of the one and the endothelium of the other, but do not directly invade either till, in the case of the muscle, the cross-striation is lost and the sarcolemma destroyed as above. There may be marked proliferation of sarcolemma nuclei, as in the fibre below, which still retains its characteristic structure.

303, 304, and 305). Bundles in which the cross and longitudinal striations are retained may have for their neighbours others in which only the longitudinal striation remains, or in which the fibres are broken into longitudinal columns, irrespective of their true structure, or into discs (*Fig.* 304), the whole appearance in such an area recalling the old discussion on the structure of muscle in the middle of the last century, in which Bowman took so prominent a part. This fragmentation of the muscle is therefore nothing specific, nor is it due either to penetration by gas or formation of gas in the fibrils. It can be obtained by inappropriate fixation at any time from the muscles of any healthy laboratory animal, and it will be recalled that the injured portion of gracilis muscle had been preserved entire, and was therefore not fixed perfectly. The fragmentation can be avoided (see *Figs.* 298, 303, and 307) by appropriate

fixation even of heavily infected muscle, by making small thin slices with a very sharp knife and fixing immediately in Zenker's solution at a temperature of 38° C., and thereafter carefully manipulating. Nevertheless, the muscle

FIG. 304.—Advanced infection.—Very numerous bacilli between fibrils, some showing spores; absence of leucocytosis: fragmentation of muscle into cylinders and discs.

fibres may have an abnormal tendency to longitudinal and cross-fragmentation. Throughout they have a somewhat swollen appearance (see *Figs.* 316, 327). They tend, when stained with eosin, to look like ground glass, and

FIG. 305.—Spread of bacilli across the muscle along the track of the large vessels, and longitudinally between the muscle fibrils along the capillaries. The capillary network is well shown, owing to displacement or accidental removal of muscle fibrils. Great dilatation of one capillary. Absence of leucocytosis.

except near the actual wound, there is some proliferation of the sarcolemma nuclei, never, however, advancing to the formation of tubes of cells such as are seen in sterile muscle wounds, or even so far as fragmentation of the

sarcous substance. Near the insertion are some muscle fibres looking like sections of sponge, and showing therefore what is called vacuolar degeneration, such as is commonly found in muscle fibres where there has been ordinary œdema.

The appearances described apply to the fibres forming as it were the core of the muscle. The muscle sheath shows hæmorrhage and leucocytic infiltration, also dilatation of its vessels, and the capillaries are engorged with blood, some of them containing polymorphonuclear leucocytes, with which also the fibrous tissue is densely infiltrated. This leucocyte infiltration is most marked only where the micro-organisms are in variety. It also extends into and between the adjacent muscle fibres over a distance of several longitudinal layers, but then ends sharply between two bundles, so that there is a sharp contrast between the core as it were and the rind of the muscle (*Fig.* 306). The margin of this leucocyte infiltration corresponds, moreover, with the point where the endomysial spaces between the muscle fibres become crowded with long bacilli (*Fig.* 306). Only here and there is there any penetration of these bacilli into the zone of leucocytic infiltration. The leucocytes at the margin are actively phagocytic of the long bacilli. In the block containing the muscular insertions, the acute inflammatory condition in the sheath has greatly moderated, and the fibrous tissue is now very cellular and the vascular changes are less noticeable. There is also a moderate leucocytosis uniformly distributed between the widened endomysial spaces. In the prolongations of the tendinous tissue between the muscle bundles at the insertion, the vessels do not present any obvious departures from the normal beyond engorgement. The majority of the fibres near the insertion retain their characteristic striations.

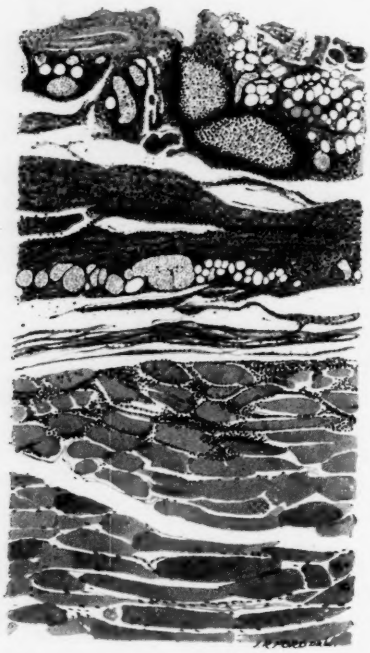


FIG. 306. — Section of gracilis femoris through sheath into muscle.— High-power view of top left-hand corner of *Fig.* 300, showing great engorgement and thrombosis of vessels in sheath, and leucocytic infiltration extending into superficial layers of muscle. Where the leucocytic infiltration ceases the bacilli are in enormous numbers between the fibres.

Here and there, both between muscle fibres and bundles, as well as beneath the sheath, and in the sheath itself near the wound, but not near the insertion, there are numerous large bubbles visible to the naked eye, and the microscope reveals other smaller ones. In the muscle they are invariably between bundles of fibres (*Figs.* 303, 304, 305, 307), never in them; the manner of the arrangement of leucocytes and bacteria round the margin of a bubble is always the same—they have been pushed aside during life: as have also the muscle fibres, which, however, nowhere show signs of having been subject to pressure, signs of which are also absent in the exudate and the capillaries

between the neighbouring fibres (*Figs.* 299, 300, 301, 302). About the middle and close to the sheath there is a large patch of bundles which have an appearance indistinguishable from that shown in *Fig.* 327, which is from another specimen, and referred to later as exhibiting capillary thrombosis.

There remains to be described the manner in which the bacilli have spread throughout the length and breadth of the muscle. The great variety of organisms present at the site of injury has already been mentioned. Towards the end of the first block in *Fig.* 299 they are almost more numerous, and certainly so in the second and third blocks (*Figs.* 300 and 301); but they

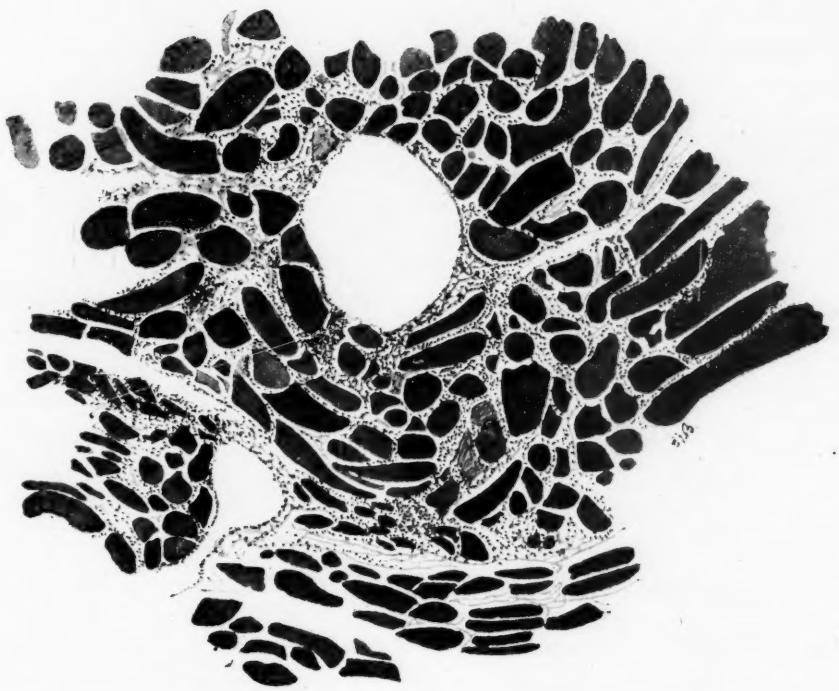


FIG. 307.—'Gas gangrene.'—Two bubbles between muscle fibres, widely separating them. Granular exudate widely separating muscle fibres elsewhere. The exudate is almost cell-free, but contains very numerous bacilli, which also surround little bubbles. Muscle fibres have lost their striation and have a typical ground-glass-like appearance; the sarcolemma nuclei have also disappeared; in places they show irregular fragmentation invaded by bacilli.
Four hours after death. Gram plus eosin.

now seem to be a pure culture of long bacilli up to the insertion of the muscle. The sheath is only invaded up to the end of the second block. At the insertion the number of bacilli is noticeably reduced.

As has been observed already in the case of the segmental muscles, there is no evidence that the bacilli are essentially 'muscle feeders;' indeed, they are present in the greatest numbers, not where the muscle has been immediately killed by the missile, but in the interfibrillary spaces of the portion intermediate between this zone and the insertion—i.e., they have extended in the lymphatic spaces.

In the block next to that containing the insertion, as well as in the neighbourhood of the insertion itself, it was possible to follow the mode of spread of the bacilli quite easily. They pass across the longitudinal axis of the gracilis, by growing along the track of the larger vessels (see *Fig.* 305). Once they get into a new longitudinal space, they spread along the capillaries, being closely applied to the sarcolemma of adjacent fibrils or applied to the walls of capillaries, and often arranged longitudinally; but nowhere are they found in the capillaries (*Figs.* 303, 304, 305). This description, it must be recalled, is of a muscle cut off from its blood-supply. Similarly, they only enter the fibrils themselves when the sarcolemma has been destroyed (see *Fig.* 303). Bacilli were sought for but were not found entering the tendinous insertion or the sheath itself at the insertion.

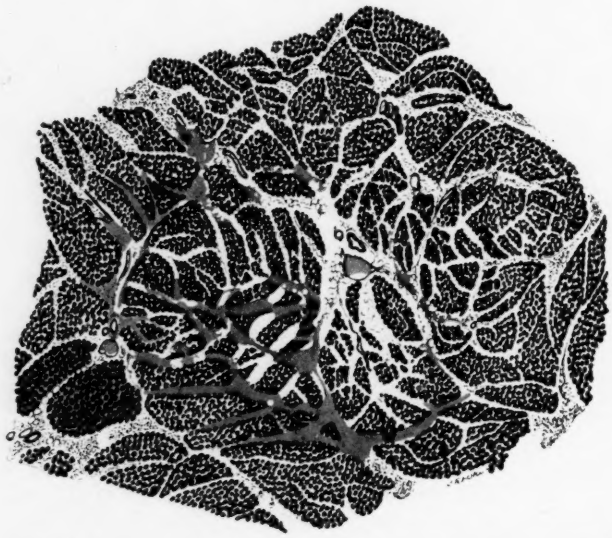


FIG. 308.—General view of margin of bacillary invasion.—The muscle was of a dark purple colour to the naked eye. The muscle bundles are widely separated, in some places by swollen endomysial connective tissue, in others by recent hæmorrhage and either older homogeneous blood or lymph. The muscle fibrils are also separated in some areas, but closely packed together in others. The larger vessels and the capillaries stand out boldly. Here and there in the freshly extravasated blood there are a few isolated bacilli; or two distinct forms of Gram-positive bacilli—a long one and a short one—are present together, as at * in the figure.

Along the capillaries, in the region where the infection is moderate, the leucocytes are actively phagocytic (*Fig.* 303). The capillaries often exhibit irregular swellings (*Figs.* 304, 305); and were the circulation working it may be surmised hæmorrhages would be frequent.

The general pathological picture presented by the invasion of muscle by a pure growth of bacilli is well brought out in *Fig.* 307, which was obtained post mortem from a case of gangrene of the thigh in which the femoral artery had been severed. The piece of tissue had been removed from a site well above the injury to the artery. The appearance is also characteristic of that seen in material obtained at operations from situations where the growth of bacilli is very active, and leucocytic infiltration and proliferation of

the sarcolemma nuclei are absent or are not prominent; in such a post-mortem example this absence may be merely the results of deprivation of the blood-supply. The ground-glass-like appearance of the muscle fibres, their wide separation, and the filling of the intervening spaces with enormous numbers of bacilli, are all brought out. Two bubbles are shown, together with the typical arrangement of the surrounding structures; the conditions show the absence of evidence of pressure disturbances. One bubble is in process of moving along the interfibrillar spaces. In this instance the organism resembles the *B. aerogenes capsulatus*; it is present apparently in pure culture, the majority of the bacilli showing spores.

Several instances have been observed in which the pectoral or gluteal muscles have become gangrenous, and in some the extension of the gangrene corresponds with the main arterial supply which has been cut off, the extension being defined by the zones where there is a ready collateral supply.

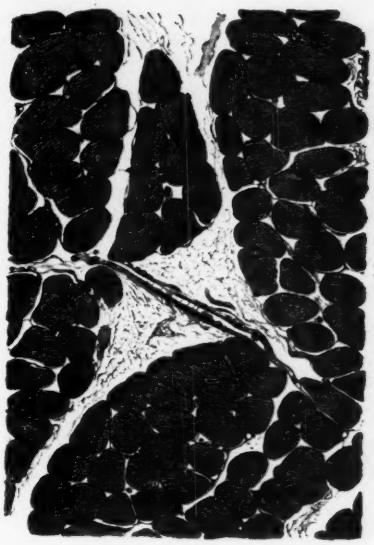


FIG. 309.—Capillary crossing distended endomysial connective tissue containing granular fluid and swollen connective tissue.—The capillary wall is swollen, and there is some irregular grouping of the nuclei of the endothelial cells. The muscle fibres have not lost their striation, and sarcolemma nuclei are present.

2. *The Portion Retaining its Blood-Supply.*—The histological picture presented by the portion of a muscle still receiving its blood-supply when it is invaded by bacilli, is very much more complicated than in the case of the distal portion. The latter portion gives, however, a good skeleton, as it were, of the process, and permits of the apparent confusion in longitudinal sections being unravelled. If extravasated blood, engorged and ruptured capillaries, and thrombosed veins be fitted into the skeletons provided by *Figs.* 303, 304, 305, 306, so as to cover wide areas, and elsewhere the skeletons be left as they are, or filled in in a patchy manner with additions here and there of leucocytic aggregations, a general conception of the picture presented by a longitudinal section in the advanced bacillary invasion of living muscle can be conceived. On the whole, the absence or scarcity of leucocytosis contrasts strikingly with its domination over every other feature when the micro-organisms are the pus-forming cocci, either in pure culture as in *Figs.* 323 and 324, or mixed with 'anaerobic' bacilli as in *Fig.* 298. The absence of leucocytosis is also a striking feature at the advancing margin of bacillary invasion (*Fig.* 308), and in the œdema. It is also absent in the peritoneal, pericardial, pleural, and œdematous fluids of rabbits, guinea-pigs, and mice which have been infected with cultures of these bacteria. For all of which reasons it appears clear that the leucocytes may not set up an effective protective barrier against the invasion of healthy tissue by massive doses of these bacilli. Not an

inflammatory leucocytosis, but an inflammatory leucopenia, is characteristic of the pure bacillary invasion of muscle; and this must be borne in mind in

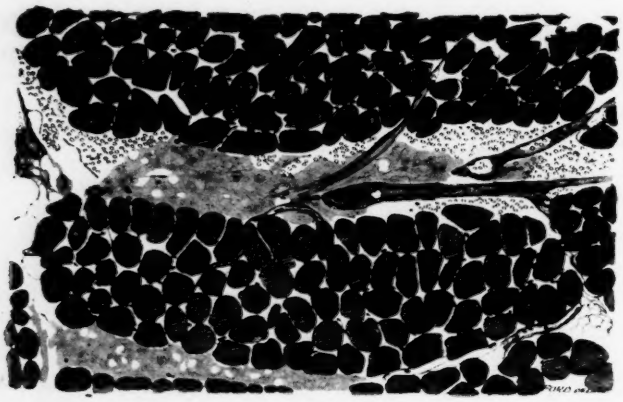


FIG. 310.—Small arteriole giving off capillaries which are in process of disintegration or have already ruptured.—Excess of endothelial cells in arteriole and capillaries. These vessels lie in old extravasations or in recent hæmorrhages. Sarcolemma nuclei are present in the muscle fibrils.

judging of the apparent efficacy of any method of treatment which relies on the abundant formation of pus as a sign that all is going well, or aims even at maintaining a pus poultice for days on end without interference.

The margin of bacillary invasion merits more detailed description in this connection, and also because suitable material for the purpose is difficult to

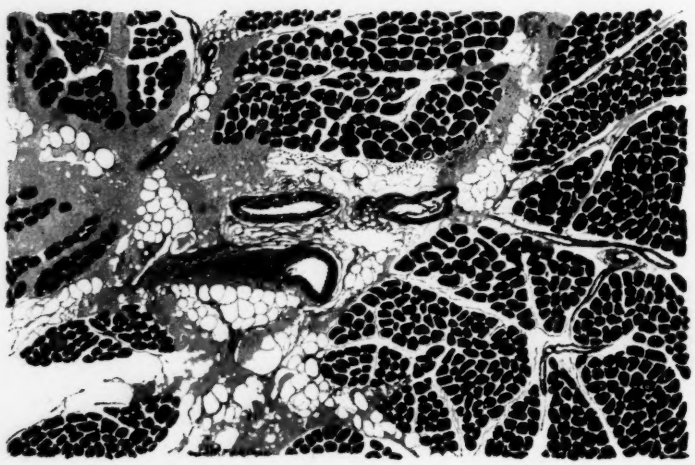


FIG. 311.—Arteriole and two small veins of the endomysium.—The arteriole shows little departure from normal, perhaps excessive cellularity, which is more marked in the veins, of which the walls of one are in process of separation. Other smaller arterioles and capillaries show similar conditions. Much homogeneous extravasation into the endomysium and between muscle bundles, which are very unevenly separated.

obtain, and has involved a quite disproportionate amount of laborious cutting and examining of serial sections. *Fig.* 308 gives a general survey in cross-

section of the margin of invasion in a long muscle of the leg at the site of amputation; *Figs.* 309 to 316, with their descriptions, supply the essential details. *Fig.* 308 serves as a skeleton on which to supply the details which are picked from seven different areas in it, with an additional area from a neighbouring serial section.

The muscle fibrils in some places exhibit striation, in others they appear swollen and homogeneous, and there are irregularities in the numbers of sarcolemma nuclei from one area to another. It will be seen that the muscle bundles and fibres are unusually closely packed together in some areas, and visibly separated in others. In the latter, the areas and spaces on the one hand are full either of freshly coagulated or of older, altered, and homogeneous blood; on the other hand, they contain only the connective-tissue elements of the endomysium, which can at times be recognized to be abnormal. The connective-tissue fibres are swollen as in œdema, they have been readily separated in the manipulation of the material at the time of cutting off a piece for fixation, and the capillary walls stand out with abnormal prominence. At times there is a granular-like material (œdematous fluid) between the fibrils. At a later stage all the muscle fibres may be swollen and homogeneous, and tend to stain an intense blue with hæmatoxylin; finally, they exhibit fragmentation as described on an earlier page.

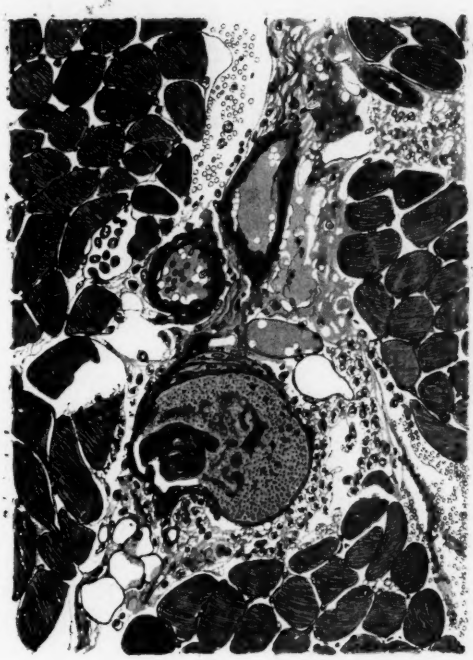


FIG. 312.—Two arteries and two veins.—A widely-distended vein containing a fibrin thrombosis with much blood and some leucocytes, the latter also invading its walls and infiltrating surrounding tissue. Another vein with cellular wall which has ruptured, permitting escape of hæmolysed blood. The endothelium of the two arteries shows proliferation and some degeneration; one contains altered blood.

The first of the sequence of events in the circulatory disturbance appears to be accumulation of fluid in the endomysial spaces, due either to increased transudation through the altered capillary walls, or to diminished absorption. No evidence can be adduced for the latter assumption; but the swollen, and at times vacuolated, endothelium (*Fig.* 317) of the capillaries and veins is evidence that they are not fulfilling their circulatory functions. At a later stage capillaries rupture, and even veins do so. Although lymphatics are not known to occur even in the large divisions of the endomysium of voluntary muscles, it is common to see engorged or ruptured vessels which either are lymphatics, or are very distended capillaries filled with altered, granular blood-débris looking like the normal contents of lymphatics (*Figs.* 312, 313, 318, and 319). Disin-

tegrated capillaries and veins are common, and embedded either in recent hæmorrhage or in altered homogeneous blood. Veins showing a fibrin thrombosis, and even adhesion of red blood-corpuscles to degenerated endothelium,

FIG. 313.—Artery, vein, and lymphatic, showing degeneration and loss of endothelium.—Red blood-corpuscles and leucocytes or hæmolysed blood adhering to elastic lamina of artery which is laid bare. Disintegration of walls of vein. Rupture of lymphatic.

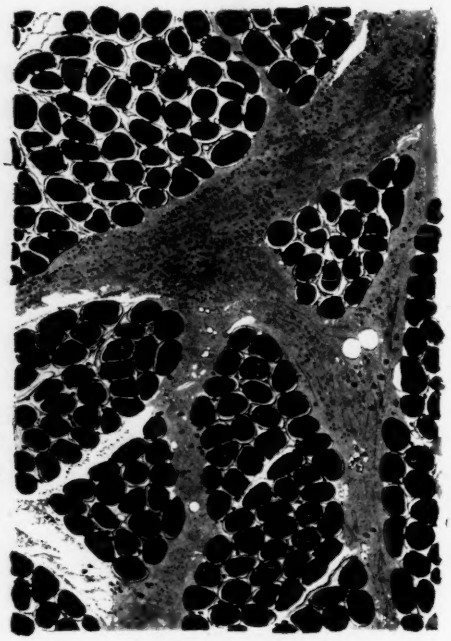


FIG. 314.—Mingled old and recent extravasation into endomysium.—Empty capillaries standing out between fibrils; early swelling of muscle fibres; sarcolemma nuclei lost; loss of striation in muscle fibrils. Note the presence of leucocytes in normal proportion.

are easily found. The endothelium may be lost, or may be in all stages of degeneration, or seen in proliferation (*Figs.* 317, 318, 319). The altered and homogeneous blood may be met with inside vessels as well as extravasated; and it is well to note that the blood in both connections shows no excess of polymorphonuclear leucocytes, but rather the reverse, and that the mononuclear cells stand out at times quite distinctly. Extension by way of the connective tissue surrounding veins appears to be common, and to explain the advance of infection, e.g., from the leg to the thigh. This is not an extension by muscles (*Figs.* 318, 319).

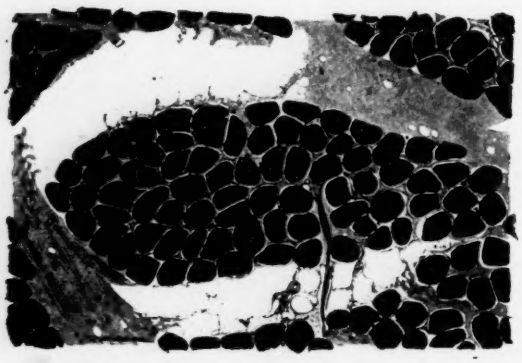


FIG. 315.—Homogeneous extravasation of hæmolysed blood or lymph. Disappearance of capillaries between fibrils, which have almost lost their striation, and show early swelling. Absence of leucocytosis.

The question of the involvement of the lymphatics has received great attention, without quite definite conclusions being arrived at. By examining long longitudinal strips of the subcutaneous tissue, it has been possible to discover strings of mononuclear cells without there being any evidence of a containing endothelial membrane; and in one example remote from the wound a large lymphatic was encountered in transverse section, the endothelial lining being puckered and folded, and the lumen blocked with

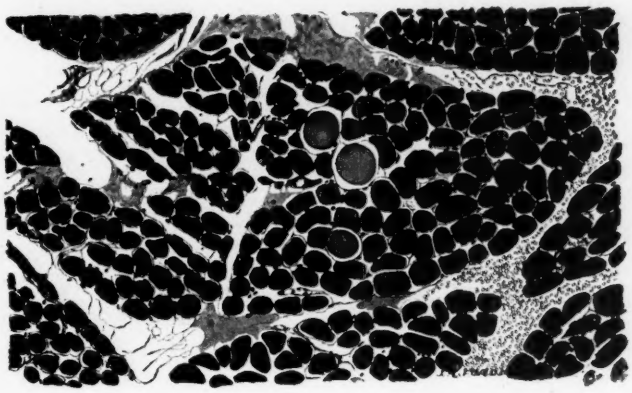


FIG. 316.—Old and recent extravasations of blood and lymph or hæmolysed blood. Capillaries still evident. Muscle fibres in various stages of swelling, to assumption of homogeneous ground-glass appearance, which may come to affect all the fibres uniformly.

mononuclear cells. It may be that many of the lymphatics are simply obliterated by pressure, or collapse because of the loss of blood-pressure consequent on the disorganization of the capillary and venous arrangements, the pressure in lymphatics being as low or lower than the blood-pressure in capillaries. In other inflammatory conditions the lymphatics are involved in a manner parallel with the small veins, and it would be strange were it otherwise in the present relations.

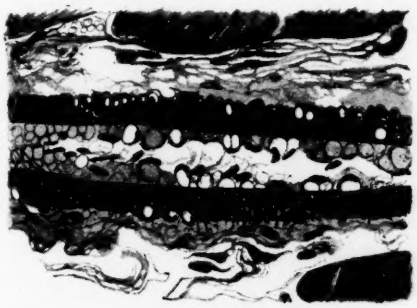


FIG. 317.—Small arteriole showing degenerating endothelial lining and walls.—The cells of both show vacuolation, most marked in the endothelium. There is proliferation of the nuclei of the muscular coat. The characteristic shape of the endothelial cells, as well as of their nuclei, is entirely lost.

From a piece of muscle remote from the site of infection twenty-four hours previously. The section of muscle under a low power is scarcely distinguishable from that shown in *Fig.* 308 for man. Rabbit killed twenty-four hours after injection.

By careful searching, bacilli can be found inside vessels obtained from the human subject at amputation and above the injury, but they are not common except where the blood is broken down (see *Fig.* 320). Their presence here at the margin of invasion indicates that they are constantly entering the blood-stream. They have been found both in the blood and in the walls of muscle veins in rabbits, guinea-pigs, and mice as a lethal issue was approach-

ing after intramuscular injection of cultures. Bacteria can often be found in the distended endomysial spaces, and then lying in freshly extravasated blood between intact capillary walls and the muscle fibres, as if they had been carried along with the spreading blood; they must, however, be either in these spaces and undetected, or have been present in the capillaries and veins whose rupture is the source of the hæmorrhages. Under experimental conditions in the rabbit, isolated bacilli have been found lying between the densely packed muscle fibres.

FIG. 318. — Deep artery, vein, lymphatics, and nerves from lower end of popliteal space.—The smaller vessels, nerves, and lymphatic to the left of the figure are shown under a high power in *Fig.* 319.

To sum up, there is histological evidence that the products of the bacilli damage the vessels and the muscle fibres and the endomysium ahead of their massive advance, and less evidence that the lymphatics are similarly involved. The process of bacillary invasion is further assisted by the motility of some of them in the fluid poured out into, but not absorbed from, the tissues, and by the disorganization of the vascular arrangements. Three and a half hours after injection of 1 c.c. of culture into the back of the thigh in rabbits, numerous

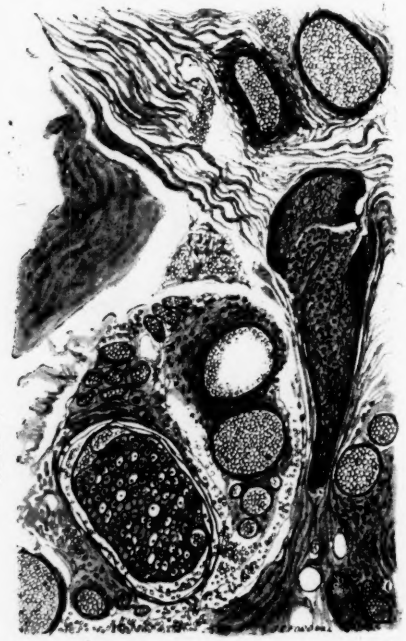


FIG. 319.—Deep artery, vein, lymphatic, and nerves from lower end of popliteal space; thrombosis of larger artery, vein, and smaller vessels (see *Fig.* 318).—The blood sits directly on the elastic lamina, which is permeated by blood in some places. Infiltration of walls of vessels by leucocytes from within. Thrombosis of lymphatic by fibrinous clot. Hæmorrhages under sheath of nerve and into its substance. The extension of these processes explains how gangrene passes upwards from below the knee.

High-power view of portions of the whole field shown in *Fig.* 318.

bacilli can be found half-way up the anterior abdominal wall in the extensive œdema. The larger arteries remain relatively exempt, and keep on pouring

blood into the invaded area, where, owing to the rupture of the capillaries, the disintegration of veins, and disturbance of the lymphatics, no means exist for an adequate return flow. In places the end-result is nothing short of extensive intramuscular hæmorrhage, with the further provision of fresh masses of tissue ideally suited for bacterial growth. At times this process is augmented by rapid and by remote thrombosis. It will be necessary to consider in more detail the evidence that the muscle fibres are injured by bacterial products, and also the evidence that thrombosis can cause a most important and grave aggravation of the whole condition, although it has been

FIG. 320.—Vein of endomysial space. — The dense surrounding tissue is heavily infected by bacilli. The hæmolysed blood in the vein also contains bacilli, which, continuing to multiply in the blood, must either enter the blood-stream higher up or lead to the production of an ever-increasing column of destroyed blood. Under a high power, coats of the vein show degeneration as in *Fig.* 317.

found only in some of the examples examined. The probable reason for the accompaniment of thrombosis in some cases and its absence in others will be discussed in a later paper, under the heading of experimental bacillary invasion of muscle and production of thrombosis.

II. THE INTERFERENCE OF BACTERIAL PRODUCTS WITH MUSCLE REGENERATION AND WITH THE FORMATION OF GRANULATION TISSUE.

Reference has been made in a previous paper[1] to the proliferation of the sarcolemma nuclei—which surround themselves with cytoplasm, thus leading to the formation of tubes of cells enclosed in the sarcolemma, such as are familiar from the figures in text-books (see previous paper, *Figs.* 251 and 253, pages 451 and 453)—and frequent reference has been made above to the proliferation of sarcolemma nuclei under different conditions, thereby suggesting that it may have a significance which has not hitherto been fully recognized. Reference has likewise been made to the absence of such tubes

of cells, and the aborted attempts to produce them, in infected muscle. It may be said that these cells become free in large numbers, and at certain stages in a healing muscle their presence dominates the whole field, as in *Figs.* 321, 322. The process is a pure tissue reaction of muscle cells, plasma cells, and endomysial and other connective-tissue cells; polymorphonuclear leucocytes may be said to be absent.

FIG. 321.—Regeneration of muscle five to six days after injury, under sterile conditions.—The surface is covered with healthy granulation tissue, and separated from the injured muscle by clot. The proliferated muscle cells have become free for the most part, and dominate the whole field between the remains of other fibres; some multinucleated muscle cells are seen. *Fig.* 322 shows a high-power view.

Infection by Pus-forming Cocci.—It is now well known that the micro-organisms speedily diminish in variety and number on the surface of healthy granulating wounds. As a rule, in apparently healthy granulations on which micro-organisms are demonstrable by smear preparations, they are cocci; and on sectioning they are discoverable by staining only in the most superficial layers, say within at most two to three millimetres of the surface. But there are many exceptions to this rule, and the formation of small abscesses in granulation tissue is common. The influence of the infection may extend deeper than the cocci, and involve the subjacent muscle. Then the pure tissue-reaction described above does not occur. There is often a marked proliferation of the nuclei in the muscle fibres, the contractile substance being broken up and crowded between the new cell-formation within the sarcolemma

which may often be recognizable. When the proliferation is thus marked, it has certainly been antecedent to the influence of the bacterial products being felt.

More usually there is only a moderate proliferation (see *Fig.* 298), and the new nuclei do not become free, although surrounded by cytoplasm. They remain in the fibrils, between which the whole field is dominated by polymorphonuclear leucocytes, which sometimes enter the fibrils, but often do not do so. An appearance as if polymorphonuclear leucocytes had entered the fibrils is often imitated by the fragmentation which the newly-formed muscle nuclei themselves are very liable to undergo when in infected surroundings.

The contrast between the aborted and the normal processes may be illustrated by comparing *Fig.* 323 with the preceding *Figs.* 321, 322 of muscle

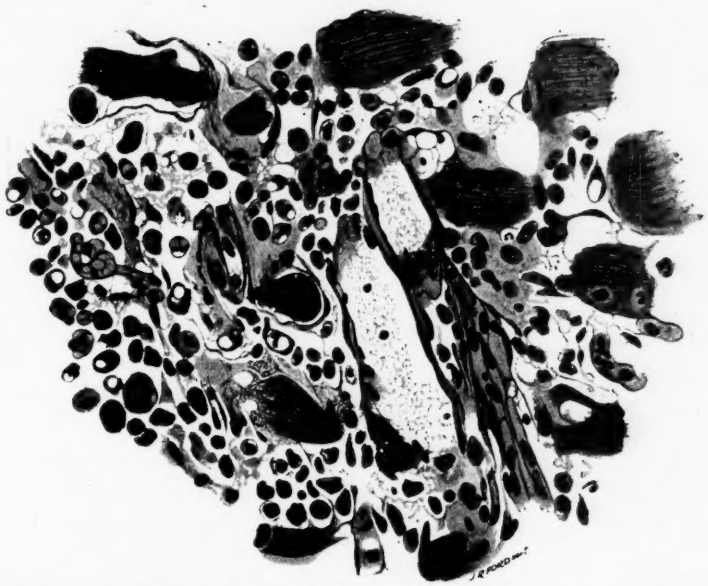


FIG.. 322—Regeneration of muscle (high-power view).—Pure tissue reaction of muscle cells, plasma cells, and connective-tissue cells. Polymorphonuclear muscle cells are almost absent. Compare *Fig.* 321.

regeneration beneath sterile granulation tissue. *Fig.* 323 has been prepared from tissue excised by Captain Hartley, and although no cocci are recognizable between the muscle fibres, they are numerous in the overlying granulation tissue.

The coccal invasion of a wounded surface may be so intense that granulation tissue is not formed, as in a specimen provided by Captain Morrison. It was from a wound of the anterior aspect of the leg. The wound had been excised, and four days later, while undergoing treatment with salt solution, was noticed to exhibit a peculiar bluish mottling. Within another twenty-four hours these areas had become pale grey; they seemed to have passed into a necrotic condition. The microscopical appearances are shown in *Fig.* 324. The surface is covered with a dense layer of cocci in pure culture. Consideration of all the circumstances leads to the conclusion that this growth had

occurred after the preliminary excision of the injured tissue, from organisms which had already penetrated deeply.

The absence of any attempt at the formation of granulation tissue beneath this layer of cocci strikes one at once; it lies directly on the muscle bundles, which are widely separated, and present that ground-glass-like appearance without any sarcolemma nuclei frequently alluded to above. The capillaries are recognized between the muscle fibres as empty tubes.

Along some of the larger septa of the endomysium the cocci have extended downwards to the deeper layers of muscle, being frequently in short chains of three or four. These streptococci are plainly recognizable down to the deep clot (*Fig.* 324) below which the vascular supply is active; but they have not entered between the individual fibres of the surface muscle. The layers of muscle may be divided into three zones: (1) The outer layer just described; (2) A zone in which there is intense leucocytic infiltration of the connective tissue between the muscle bundles and fibrils, together with a widely disseminated infection due to a pure growth of streptococci. Many of the deeper muscle fibres in this zone have entered on a stage of attempted regeneration which has aborted, some of the fibres being heavily infiltrated with leucocytes; (3) A third zone, separated from the second by a layer of clot, showing a slight leucocytosis, some proliferation of the sarcolemma nuclei, and distended vessels and capillaries, but on cursory examination seeming on the whole to show little more than the disturbance caused by the surgeon's knife; however, the examination of serial sections showed that thrombosis had extended into vessels in this region.

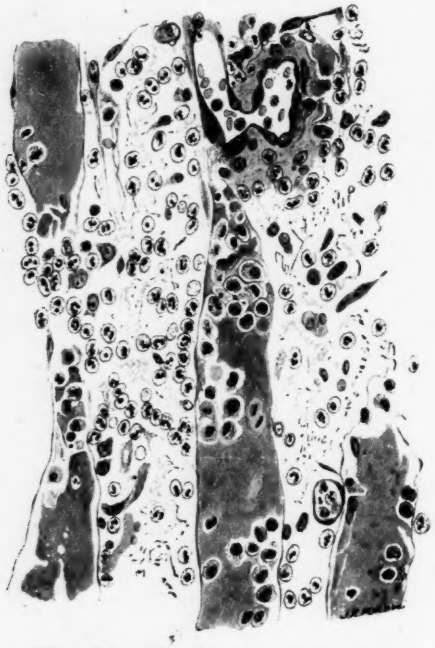


FIG. 323.—Abortive attempt at regeneration of muscle fibre in an area where the remote effects of coccal invasion of granulation tissue are still felt.—The new muscle cells remain within the tube of the sarcolemma for the most part, the space between the fibres being crowded with leucocytes. Compare *Fig.* 322.

The condition of the vessels requires more detailed consideration than the condition of the muscles. In the centre of *Fig.* 324 a number of arterioles and veins are shown. They are all thrombosed. In the arterioles—which stand out prominently in tangential section—the intravascular clot is seen to be largely fibrinous; it is entirely so in the accompanying vein. In some of the vessels extensive deposition of blood-plates is observed, without complete thrombosis. In yet others the blood has conglutinated, the outlines of the individual red cells being lost. In short, all stages and forms of thrombosis are met with, and together with it there are often hæmorrhages. In serial sections the prominent artery or vein can be traced towards the surface, and

down in the deep third zone other vessels appear. All present similar features —thrombosis in various stages—so far as their courses can be followed. The deposition of blood-plates on the endothelium, and the presence of the excess of fibrin, proves that the process had originally been slow in the vessels in which these phenomena are seen; but it has been acute in others, where the red thrombus indicates that blood had coagulated as in an extravascular clot, or even more suddenly by conglutination. The blood-plates and the fibrin have been deposited first on the endothelial walls, indicating that the cells

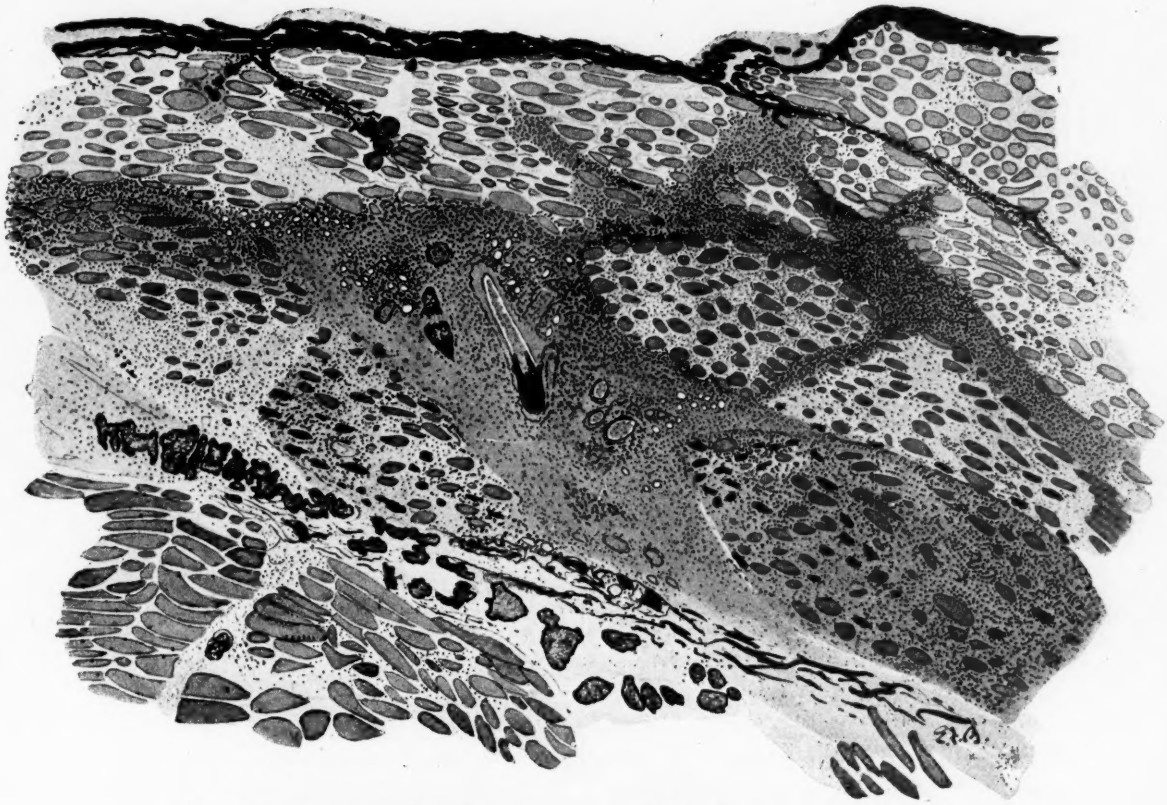


FIG. 324.—Streptococcal invasion of muscle.—The black layer on the surface represents dense masses of cocci, which extend downwards between the muscle fibres to the deep clot running obliquely across the figure, where they are recognizable in short chains of three or four. There are no leucocytes on the surface or between the superficial muscle bundles, where the capillaries are recognizable as empty tubes. Many thrombosed vessels are shown (for details see text). Here and there are seen darker muscle fibrils which have entered on a regenerative process which has aborted. The whole field in the deeper layers is dominated by polymorphonuclear leucocytes.

lining the vessels are abnormal, and in part at least responsible. Subsequently the thrombosis has extended rapidly so as to form a red clot of the rest of the blood content. The progress of these events had given rise to the clinical appearances which attracted the surgeon's attention. Although no cocci can be seen in the blood or vessel-walls, the latter are infiltrated with leucocytes in some parts, and the conclusion may be drawn that the extensive thrombosis of the small vessels was due to bacterial influence, and that, if thrombosis was

not actually present, the process was already beginning at the time when the wound was cleaned by the surgeon. The failure or delay in the formation of granulation tissue, and the entire absence of leucocytes in the surface layer, or of blood in the capillaries in that area, may be thus explained. Under bacterial influence the thrombosis had subsequently extended, and rendered fresh muscular areas suitable soil for the growth of the cocci. The progress of infection has not been very extensive in this instance, but the wound remained very refractory, and there was sloughing. The manner in which the condition appears to have taken place may throw light on other rapidly extending infections involving whole limbs. Streptococcal infection may appear to be limited to the granulation tissue. Pale, anæmic, dry granulation tissue is familiar and is usually associated with infection. Sometimes this state of the granulation tissue is associated with a slight icteric tinge of the skin, and in two cases where this was present it was found possible to isolate a streptococcus from the blood.

Infection by 'Anaerobic' Bacteria.—The following example illustrates the action of the bacillary infection on granulation tissue, and on the subjacent muscle. The femur was fractured just above the knee-joint, the vessels being spared; but the condition of the wound necessitated amputation, which was performed in the upper third of the thigh, owing to there being multiple flesh wounds leading down to the bone. These wounds had been treated with eusol, and were covered with pale dry granulations. A suitable slice of this granulation tissue, including subjacent muscle, was placed in warm Zenker's solution. To the naked eye a sharp delimitation between the granulation and underlying tissues was apparent. The granulation tissue varied from a half to a twelfth of an inch in thickness, and seemed to lie on the surface of the muscle without any sort of gradual transition. Under the microscope the margin between them is seen to be equally sharp, and there has been practically no reaction of the subjacent muscle fibres or endomysium such as occurs usually and leads to a mingling of the various cellular elements in the manner shown in *Figs.* 321 and 322. Lying on the surface of the muscle fibres, and covered by the granulation tissue, there is a large number of woollen fibres (khaki), and some vegetable fibres. The extraneous matter is also found running between the strands of muscle in two situations. Where they have not been torn out in the preparation of the sections, the foreign bodies lie embedded in large multinucleated giant cells. When examined with a low power, the granulation tissue itself presents, on the whole, little departure from the ordinary, except that the cellularity varies, and in some parts the capillaries appear unduly dilated. Where the cellularity is diminished, the capillary walls are prominent, as if punched out on a granular translucent background, owing to the absence of cells arranged around them. With a higher magnification, the excessive cellularity of one area is more apparent, and the scarcity of the several types of cells characteristic of granulation tissue is confirmed in the other. In the latter the connective-tissue fibrils appear swollen and widely separated, as if by fluid, the appearance being almost myxomatous in areas where it is most pronounced.

The capillaries present varied appearances. Some do not differ from the capillaries in the healthy portions, but some are dilated, and from

some hæmorrhages have occurred. In others a deposition of platelets is seen to have taken place; and in fact all stages of thrombosis up to complete obliteration of the lumen, and even canalization of thrombi, are to be observed in vessels with more mature walls, i.e., in pre-existent arterioles and veins below the granulation tissue. Partial thrombosis and proliferation of the endothelium inside the vessels is also present.

Staining by Gram reveals two different infections in separate areas. On the one hand, numerous cocci are present near the muscles in one spot, occurring sometimes singly, but more usually as diplococci (streptococci), and occasionally in little groups like staphylococci. They are not found within or in the immediate neighbourhood of the giant cells, although still within close range of them. In the same neighbourhood they are also present where there has been hæmorrhage, and in the dense connective tissue of an intramuscular septum, as well as in the connective tissue of an endomysial space between the contiguous muscle bundles. An abscess was probably in course of formation in this area. On the other hand, in the more extensive œdematous-looking granulation tissue no cocci can be found, but colonies of a long bacillus occurring in threads are common, deep down near the muscle fibres, especially in the neighbourhood of dilated capillaries on the walls of which a deposition of blood-plates has already taken place. These chains of bacilli stained irregularly with Gram, and recall the bacillus of malignant œdema. The neighbouring muscle fibres show no signs of reaction; they lie widely separated by cell-free spaces.

The muscle tissue at the site of amputation presented a perfectly healthy picture, as did also that deep down from the granulation tissue, so that the major infection, at the site of fracture, cannot be made responsible for the conditions of the muscle fibres subjacent to, and in granulation tissue obtained from, a second wound at a distance from that which necessitated amputation. They may reasonably be ascribed to the products of organisms present locally.

In another instance, two areas in an otherwise healthy granulation tissue remained refractory. On excision they were found to contain khaki, and to exhibit thrombosis of vessels and a wide œdematous separation of the muscle fibres, which in places were embedded in fibrin lying on the surface without any attempt at the formation of covering granulations. No cocci were found, and only a few bacilli staining irregularly by Gram. The absence of leucocytic infiltration was striking. While up to the present I have not met with leucocytosis associated with bacterial invasion of granulation tissue and the subjacent muscle, I have come across one case in which masses of a large Gram-positive coccus occurred without a vestige of leucocytic reaction surrounding them. The condition proved very refractory to treatment.

The examples fulfil the purpose of illustrating that both coccal and bacillary invasion may be present separately in granulation tissue which is healthy where they are absent, and by their presence give rise to an unhealthy condition, even thrombosis of the vessels, and also inhibit muscle from actively participating in healing.

The contrast between the preponderance of leucocytic infiltration in coccal infection and its abeyance in bacillary infections is striking; but the evidence is not yet sufficient to determine whether this apparently important

distinction always obtains, or if it represents merely a phase in the progress of infection, e.g., is determined by the dose.

Healing by granulation has been allowed to play a great part in the healing of gunshot injuries. Its chequered course is often the cause of grave concern. It is not proposed to enter into a discussion of inflammation, or of the relative importance of the vascular and cellular phenomena. The essential importance of the vascular phenomena, which result in the enormous new capillary development of granulation tissue, lies in the fact that without new capillaries no attempt could be made by other tissues to fill up a gap. It is the absolutely essential scaffolding for tissue growth, as is proved to demonstration by growth in vitro, and by the implantation of cancer. Only extremely limited microscopical growth is obtained on growing tissues in vitro. To speak of tissue growth in vitro is erroneous; there being really only a *cell* proliferation, never producing masses of *tissue*. The absence of any vascular supply and scaffolding affords an almost complete explanation. In the case of the implantation of cancer cells from one animal to another, the early provision of a new vascular (and connective-tissue) scaffolding which the cancer cells mould to their needs is essential, and its provision leads to the perfect reproduction, from a disorganized mass of epithelial cells, of the characteristic histological structure of the mother tissue. So long as the vascular supply can be provided or renewed by a fresh implantation, growth knows no bounds. If the provision of this scaffolding is interfered with by paralyzing the powers of the cancer cell to mould it to its specific needs, the cancer cells immediately cease to grow. These reasons but reinforce the old view that in inflammation the early vascular changes are fundamental. It was therefore to be expected that if bacterial products had a harmful action on vascular endothelium, such action would evidence itself in granulation tissue, and interfere with muscle regeneration. Instances have been described where this has been so serious that granulation tissue failed to develop on muscle wounds, and in which bacterial invasion and thrombosis both continued to progress.

A marked contrast exists between the healing of muscle under aseptic conditions and the interference with healing, or perhaps diversion of the normal process into other channels, which occurs in muscles remote from the actual presence of organisms. The observation that bacterial products have this action on other cells, lends weight to the surmise that these products are responsible for a modification in the endothelial cells of vessels which leads to the adherence of blood-plates and fibrin to their walls, thus aiding in initiating thrombosis. The action of the bacterial products is not disseminated throughout the body, but, like the corresponding vascular condition, it is restricted to the infected areas and the muscle fibres in the immediate neighbourhood. Interference with muscle regeneration may be proceeding under a layer of granulation tissue, which, from its being not strikingly unhealthy, or only backward in places, is regarded with little suspicion and left alone, or the refractory areas are treated in various ways in the hope that they will improve. In such cases, where it probably overlies not only microscopical fragments of khaki, but where there is also likely to be coccal or bacillary invasion of its deeper layers or of the underlying muscle, it would be better

to strip off the granulation tissue. Perhaps in many other cases, also, the time occupied in attending to the granulations would be better occupied by removing them, and, when suitable, obtaining secondary union, by means of the pure tissue-reaction which is found in the healthy regeneration of muscle, by approximating the surface of wounds.

III. THE IMPORTANCE OF THROMBOSIS IN PROMOTING THE SPREAD OF BACTERIAL INVASION.

In the preceding pages thrombosis has frequently attracted attention, and in the course of these studies it has come into ever greater prominence as a most important factor in promoting the extensive and rapid spread of bacillary invasion.

Thrombosis was well known to be a common accompaniment of the septic wounds met with before the war, to be the usual cause of secondary hæmorrhage, and to be venous in about 75 per cent of cases. There is nothing surprising in the almost constant occurrence of thrombosis in the distal portions of severed veins, in its extension to others in infected wounds, or in its not unusual occurrence in injured portions of vessels which have not been severed, e.g., in the femoral vein or artery. However, in the course of these investigations, thrombosis has been met with also in vessels, usually veins, on the proximal side of the wound; and once attention was aroused, it has been found a quite common occurrence, not only in larger vessels, but more especially in those of small and even capillary diameter. The great frequency of secondary hæmorrhage, or of the sloughing of amputation stumps, is probably not limited to my own observations, and may find a partial explanation in the presence of undetected thrombosis. Some typical examples may be quoted; they were picked out from time to time as striking occurrences before the idea that they were only isolated phases in the more extensive consequences of the bacillary invasion of muscle had occurred to me, and present a certain amount of overlapping on that account, which is all the more instructive. It has not been found possible to follow out all the details completely in one example.

Rapid Extension of Gas Gangrene from an Apparently Trivial Wound accompanied by Extensive Thrombosis.—The first authentic case of gas gangrene which came to my notice made an indelible impression. A small fragment of shrapnel case had entered the outer side of the thigh, and had then taken an upward course, only three-quarters of an inch below the surface, for about three and a half inches beneath the external aponeurosis, from near the popliteal space. The wound had been very tightly plugged, and when seen fifteen hours after it was received, the thigh was intensely swollen and the temperature was 105°, with a rapid and feeble pulse. Longitudinal incisions were made on the outer side of the thigh, permitting the escape of much blood-stained fluid, and exposing the muscles, which were very similar to smoked salmon in their colour and consistency. The patient was dead forty-eight hours after being wounded; and not only were the femoral artery and vein thrombosed, but the thrombosis extended to the iliac arteries and veins. A light applied to a puncture in the scrotum caused a blue flame, as it did also

when applied to punctures of the skin of the thigh. All this happened in the course of forty-eight hours, as the result of what appeared externally to be a trivial wound.

It was not possible to preserve specimens for histological examination at the time when the incisions were made. It can only be surmised that the colour may have been due to acute capillary thrombosis and hæmorrhage. In other instances of this smoked-salmon appearance and consistency to touch, all the interfibrillary spaces were crowded with bacilli; the capillaries were extensively thrombosed, even the larger vessels, and hæmorrhage or extravasated homogeneous blood was universal; the vessel walls were crowded with bacilli, which were present in the lumen both when it contained altered and unaltered blood. Such muscles were dead, usually full of bubbles of gas, and often already invaded by a superadded mixed infection of cocci and small bacilli such as was not met with at the actual margin of extension.

Amputation through Thrombosed Veins, with Subsequent Sloughing of Stump.—The wound involved the outer side of the leg just below the head of the tibia, the shaft of which was splintered but not fractured; the head of the fibula was comminuted. The muscles were foully smelling and gangrenous. At the operation there was some difficulty in deciding at what level to amputate, owing to the uncertain amount of oozing. The larger vessels were not noted to be thrombosed, probably owing to the general disturbance and hæmorrhagic infiltration. On dissecting the amputated leg, it was found that while the tibial artery was patent, the posterior tibial vein was completely thrombosed at the level of the amputation. All the other veins in the neighbourhood of the wound, but not actually comprised in it, were likewise thrombosed. On reporting this to the surgeon, he informed me that he quite believed it, because there had been an extensive sloughing of the stump, which would be accounted for by the pathological findings. This case was further utilized to obtain cultures, and with them thrombosis of vessels was experimentally reproduced in the rabbit, guinea-pig, and mouse.

Occurrence of Thrombosis at a Distance.—A small through-and-through wound involved the bend of the elbow; the entrance wound was anterior and external to the middle line; there was injury to the head of the radius, and fracture of the external condyle of the humerus. A drainage tube had been inserted so as to protrude from both entrance and exit wounds. When

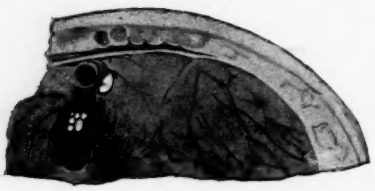


FIG. 325.—Acute bacillary gangrene.—Section of inner side of right arm above elbow, showing thrombosis of anastomotica magna and inferior profunda arteries, resulting from a wound comminuting the head of the radius. Compare *Fig.* 326.

(Drawing by Mr. W. Thornton Shiells from a specimen preserved in formalin.)

seen, the whole lower arm was intensely swollen and discoloured, the swelling extending more than half-way along the upper arm. The surgeon thought that the condition was due to the drainage tube having pressed tightly on the brachial artery. Amputation was performed at the level of the insertion of the deltoid, and the whole preserved in strong formalin. The limb was

cut into segments, when it was revealed that while the brachial artery ran its usual course and was patent, the anastomatica magna and inferior profunda arteries on the opposite side of the limb were thrombosed completely (*Fig.* 325), the thrombosis extending down into the minutest ramifications about the internal condyle. In the forearm the ulnar artery was patent, but several of the deep veins were thrombosed. Of interest was the fact that the inferior

FIG. 326.—Acute bacillary gangrene.—Section across the forearm just below bend of elbow. The wound passed from the bend of the elbow to the external condyle of the humerus, which was fractured; the head of the radius was comminuted. An incision had been made on the outer side of the arm; it shows hernia of dark discoloured muscle. Elsewhere the muscles are pale pink, and everywhere filled with gas bubbles, which are also present under the skin. The œdema of the subcutaneous tissue and fat has diminished in the course of preservation of the material. Thrombosis of large vessels. Complete involvement of whole of forearm, with extension of thrombosis and swelling up to level of deltoid.

(Drawing by Mr. W. Thornton Shiells from specimen preserved in formalin.)

profunda artery was only occluded completely throughout the middle third of its course. The gangrene had extended to all the muscles of the forearm (*Fig.* 326). Thus, an infected wound on one side of the limb was responsible for the extension of bacillary infection to uninjured muscles and for the production of thrombosis on the opposite side.

Abortion of Impending Gangrene by the Rapid Perfection of the Collateral Circulation.—The disastrous consequences of ligaturing the large vessels where infected gunshot wounds of the limbs are concerned—as the femoral artery or vein—are well known. There is immediately a great increase in the foul discharges, swelling, œdema, and discoloration; it is usually hopeless in such circumstances to look forward to the development of a line of demarcation of the gangrene. There are occasions, however, in which such ligatures must be applied, and I am indebted to Dr. Dale for details of two instructive cases. A short account of one will suffice. In this example there was a perforating wound of the right forearm, passing from the external to the internal aspect, in front of the bones, about two inches below the flexor fold of the elbow-joint. Sensation was unimpaired, and the radial pulse strong. There was considerable swelling about the wound, which was foul, and a free discharge of discoloured bloody fluid. Ten days after the injury there was severe secondary hæmorrhage. The wound was at once explored, and a ruptured false aneurysm found in the course of the brachial artery. Ligatures were applied above and below the aneurysm. The right radial pulse immediately after the operation was impalpable, and the left strong, at

11.0 a.m. At 8.0 p.m. the radial pulse could be already felt, and it gradually improved; no difference between the right and left could be distinguished three days later. The bad condition of the wound became greatly exaggerated following the ligature, and there was a great increase in the foul discharge; this gradually subsided. Subsequently to the operation the temperature rose suddenly; but with the establishment of collateral circulation it subsided, and the further course was uneventful betterment. It is impossible to avoid the conclusion that the collateral circulation was being established during the formation of the false aneurysm of the brachial artery, and that its rapid perfection was the means by which the bacterial processes were aborted in this instance. Unfortunately such anticipatory provision of an immediately efficient collateral circulation has no practical importance in long muscles. The observation has, however, the value of an experimental demonstration, although it only serves to show that interference with the blood-supply is a main cause of bacterial invasion, and that the prompt substitution of a fresh supply can obviate the otherwise almost inevitable consequences—as is the rule when the segmental muscles of the trunk are the site of the gunshot injury.

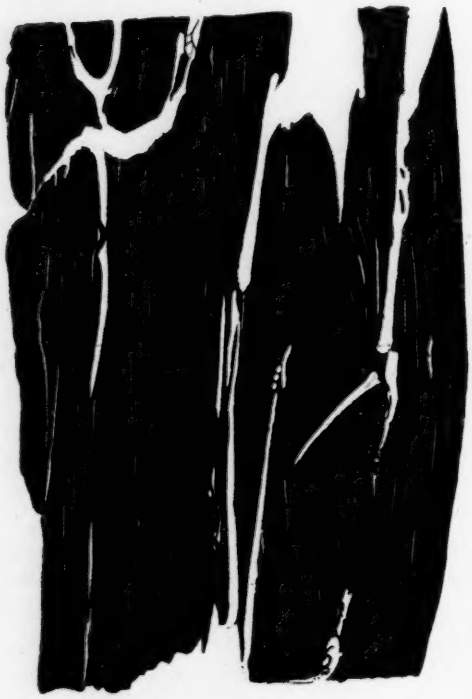


FIG. 327.—Early phase of muscle degeneration ahead of bacillary invasion (low-power view).—A piece of sartorius muscle ten inches from the wound above site of amputation. Muscle fibres swollen and densely packed together as a result of the products of bacillary invasion further down the limb. There is extensive capillary thrombosis (see *Fig.* 328).

Unsuspected Capillary Thrombosis Far Ahead of the Obvious Infection.—The wound had seriously injured the femoral artery, which according to the description supplied by Dr. Fox and Dr. Dale, who kindly removed tissue for me, was thrombosed in its distal portion. There was extensive 'gas gangrene.' Amputation was performed through the middle of the thigh, without saving the life of the patient; as a preliminary to the operation the femoral artery was tied in Scarpa's triangle, where it was found beating, although feebly. At the same time a portion of the sartorius muscle from near the base of Scarpa's triangle, and ten inches from the wound, was preserved in Zenker's fluid. On microscopical examination it shows the appearances seen in *Figs.* 327 and 328. In *Fig.* 327 the wide cracks are obviously due to the manipulation of the material, the smaller ones probably also; the latter, however, indicate that the splitting occurs along the substance of the fibrils, and not along the sarcolemma

nuclei which mark their margins. The muscle fibres themselves are swollen, and so densely packed together as almost to obliterate the fine divisions of endomysium and the longitudinal capillaries.

Here and there a small arteriole is seen filled with densely-packed red corpuscles, the outlines between the individual corpuscles being lost. Round such arterioles the muscle fibres curve as if exerting pressure. While the veins are empty, the arterioles and capillaries are full of thrombosed blood; actually the thrombosis is of the red variety, such as is usually regarded as due to the sudden conglutination of a column of stagnant blood. Extensive capillary thrombosis is usually thought to be rare, but this instance is not the only one I have met with in vessels on the cardiac side of a wound. In this case it had apparently been very extensive, for on reporting the state of affairs to the surgeons, they said they had been struck by the remarkably small amount of fluid or oozing of any description met with during the amputation; only under the skin had there been a small amount of œdema. The patient died immediately.

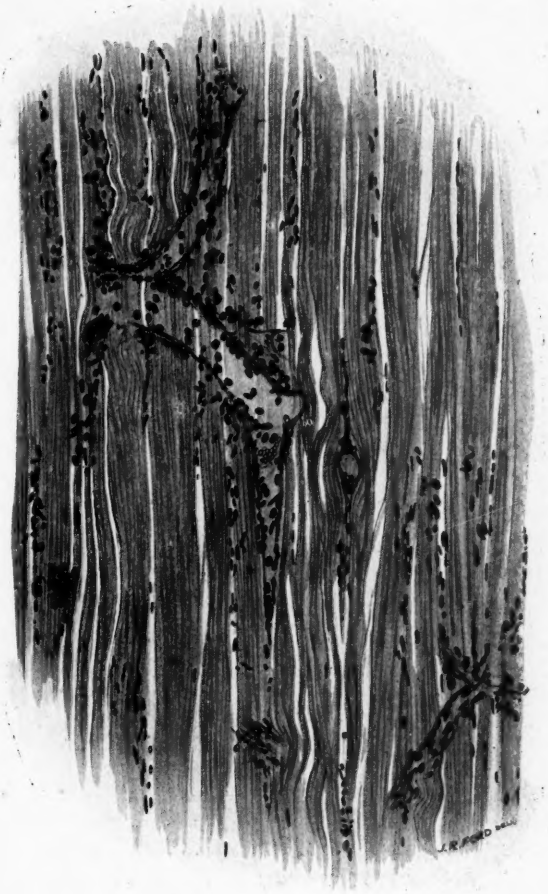


FIG. 328.—Early phase of muscle degeneration ahead of bacillary invasion (high-power view).—The muscle fibres are swollen and have lost their cross-striations. There is abnormal longitudinal splitting, the capillaries are thrombosed, and the vein empty. Considerable proliferation of the sarcolemma nuclei and venous endothelium is present. The absence of polymorphonuclear leucocytes is striking. Contrast with *Fig.* 323.

There is everywhere a marked proliferation of the sarcolemma nuclei (see ***Figs.*** **327, 328**), which it may be inferred by comparison with other cases had taken place before the capillary thrombosis and before the action of the bacillary poisons had become intense. No bacteria could be found in the thrombosed tissue by staining methods, but the condition of the muscle bundles and capillaries exhibits an early stage of the action of the products of 'anaerobic' bacilli. Conditions arising ten inches from the wound have provided by capillary thrombosis a very extensive dead tissue in which bacteria will flourish if they once find entrance to it. Muscle tissue has often

been examined at the site of amputations performed where extensive bacterial invasion was present lower down; but only exceptionally has any abnormal appearance been observed. Therefore it would appear probable that bacterial products when circulating in the blood are not of themselves the cause of these changes. They appear to be the result of a number of factors acting together, and their appearance in limited areas is determined by local causes.

Thrombosis of Brachial Artery associated with true Metastatic Deposit of Bacilli from Primary Focus in the Left Thigh.—Amputation was performed for gas gangrene of the thigh. All the muscles looked pale; there was not much œdema or swelling. An incision was made in the outer side of thigh at the time of amputation, and next day hernia of muscle had taken place at the site, and the muscle crackled on palpation, and this progressed from one group to another. For a week the temperature remained high, and there were two rigors; but the amputation stump granulated and looked fairly well, although the bone remained badly infected. Twenty-four hours before death two purpuric spots appeared just above the right elbow. On the evening of the same day the left arm felt numb, and the patient could not use it; there was nothing further to be seen. At 11.0 p.m. there was rapid swelling, and gas was crepitant from below the elbow to the axilla. There was no radial or ulnar pulse. Death occurred next day at 7.0 a.m. Captain Morrison, who supplied the above details, brought the brachial artery to me for examination. The artery was patent from the axilla to half-way down the arm, where the lumen contained a firm clot, which was free at first, but below the elbow became adherent to the wall and extended into some small branches. The histological examination showed the typical structure of a conical intra-vitam clot. Where it was adherent to the artery wall the endothelium was lost, and it sat directly on the internal elastic lamina, next to which there was a deposit of blood-plates. The elastic lamina of the vessel, and the several layers of its wall, were widely separated, and both in them, in the clot in the smaller vessel, and in the surrounding tissues, there were many Gram-positive long bacilli—no cocci were seen. It seems reasonable to regard the sequence of events here as arising in a true metastatic deposit of bacilli from the original focus in the thigh; but what local cause determined the site it is not possible to say. McNee and Mullaby have recorded a case where gas developed at the sites of subcutaneous injection, and Stokes and others have recovered the *B. perfringens* from the blood; so that there is reliable evidence to support the conclusion that a true metastatic deposit of bacilli gave rise to the condition in this case.

The examples selected above, from a much larger number, cover a wide field, and no attempt has been made to discuss, in relation to each other or in detail, many of the issues which they raise regarding the whole difficult subject of thrombosis.

It has been shown that an efficient circulation is a main factor in limiting the extension of bacterial invasion in segmental and long muscles, and that thrombosis on the proximal side of a wound is a common accompaniment of bacterial invasion. Just as the cutting off from the blood-supply determines

the invasion of muscles distal to a wound by anaerobic bacilli, so thrombosis is a common cause of the extension of bacillary invasion in muscles on the proximal side. A review of all the facts indicated in the preceding descriptions of the bacterial invasion of muscles and the associated thrombosis, brings out the following salient features, when the immediate injury to muscle and vessels and the actual implantation of organisms in these tissues is left out of account. All the vessels in the neighbourhood of an infected wound are exposed to the products arising from the growth of the bacteria and tissue destruction. At the advancing margin the bacilli have not been found invading the large vessels or even the capillaries, but they speedily do so when the latter are bathed in a pure growth, such as obtains in the interfibrillary spaces of muscle which are dying and purple in colour, or dead and like 'smoked salmon.' Hæmorrhage from capillaries and even large vessels, especially veins, is common, and the walls of small vessels—i.e., the site of election for diapedesis—have been found infiltrated by leucocytes. Nevertheless a leucocytosis is not an accompaniment of the bacterial invasion, and this infiltration may be merely a response to damage of the walls. There is evidence of damage to the endothelium of vessels and capillaries, not only in areas where the circulation has been disturbed by the immediate wounding of large trunk vessels; this damage may with reason be ascribed to the action of the products of bacterial growth. It must also be recalled that the blood circulation has already been impaired by vasomotor disturbance, weakened heart, impaired nutrition of the vascular endothelium, and a febrile condition, all leading to a slowing of the blood-stream, especially in the veins. There is evidence of blood destruction by hæmolysis, just as there is of other tissue destruction by the bacterial products. This blood and tissue destruction will of itself predispose to thrombosis by the presence of débris, altered viscosity, and by increased coagulability of the blood elements; the disposition which has been described of blood-platelets, fibrin, and leucocytes on an altered vascular endothelium will be thereby promoted, leaving out of consideration the possibility of the actual plugging of minute vessels by débris or agglutinated red blood-corpuscles. The withdrawal of fluid from the blood in the extensive œdema—often, but by no means always, stained with hæmoglobin, out of proportion to the number of red blood-corpuscles present—indicates the altered nature both of the blood and the vessel walls. But notwithstanding all these considerations which point to alterations in the blood, the circumscribed localization of thrombosis emphasizes the prime importance of the purely local causes, i.e., damage to vascular endothelium. Therefore, in the production of thrombosis, while there appear to be many contributory causes, the local causes are those which determine the site at which it will occur, and these are directly traceable to the effects of bacterial invasion of the tissues in the neighbourhood of vessels.

The chief importance of thrombosis lies in the provision of fresh areas of dead tissues suitable for the extension of bacterial invasion, and in the essential stage it provides in an ever-widening and vicious circle; and it is obvious from the examples cited that thrombosis may occur both extensively and suddenly.

IV. SUMMARY.

The clinical facts familiar to all for man, taken together with the preceding histological studies, and certain bacteriological observations on the experimental production of thrombosis and gangrene, make it clear that the bacilli in question *are* pathogenic when in combination with one another. Whatever qualification is applied to their pathogenicity, or implied by enhancing the significance of the circumstances under which they invade the body, the fact remains that they produce the most terrible surgical problems of this war, and perhaps take toll of most of the deaths from wounds which are not immediately fatal. They get away easily into the muscular tissue from the cesspool of the wound, and flourish exceedingly without the companionship of cocci or other pus-forming organisms. In a human thigh to which they have gained access directly or after passing the zone of mixed infection and leucocytic infiltration, they grow as luxuriantly as when inserted by a hypodermic needle into the thigh of a rabbit, a guinea-pig, or a mouse, and with equally fatal results.

The combinations in which 'anaerobic' bacilli occur in gunshot injuries are exceedingly virulent. While the bacilli themselves multiply mainly in the areolar tissue of the endomysium, their products actively destroy the endothelium of vessels, muscle fibres, and blood. Destruction of capillaries, veins, and lymphatics is the outstanding feature of the rapid spread of the infection, which is also accompanied by swelling and degeneration of muscle fibres, and later by the formation of gas. Constitutional symptoms arising from interference with the cardiovascular and heat-regulating mechanism ultimately supervene and usher in the end. Colonel Cuthbert Wallace[2] has recently published an impartial review of the opposing conceptions of D'Este Emery and Taylor of the pathology of gas gangrene. I have not been able to consult the articles referred to; but the view of the pathology set out in this paper seems to solve the contradictions he points out, while agreeing with his excellent clinical accounts.

The production of gas is a late, and really a subsidiary, phenomenon, which attracts attention from its mere peculiarity. I have not found it plays any part in the advance of infection, although it contributes to the later swollen condition. It arises in tissue long dead; for this reason the term 'gas gangrene' is unfortunate, owing to its implying the necessity of awaiting the detection of gas before making a diagnosis. In its place I suggest either the term 'acute bacillary gangrene,' or 'war gangrene.' The restriction of the most serious forms of infection to long muscles is explained by the vascular arrangements, and the large masses of tissue which become suddenly involved.

If the details of the preceding observations are studied and co-ordinated, the importance of the vascular lesions stands out in two ways: (1) When the arterio-venous and lymphatic circulations are maintained or, in exceptional circumstances, find rapid and efficient substitution, bacillary invasion may be stayed, probably by the constant replacement of the fluids and cells used up in combating the infection; (2) The spread of infection is promoted, not only by the actual severance of the blood-supply, but also by thrombosis, coagulation, or stagnation of the blood, especially in the capillary and venous circulation, and stagnation in the lymphatic circulation.

To all intents and purposes the latter group of phenomena are just as efficient providers of dead tissue as physical injury, and it will be just as impossible to restore the circulation in the one case as in the other. Where they have come into action, the external application of any treatment to a wounded surface cannot be successful. The danger is not on the surface, but in the depths. To be efficacious the attack on the infection would have to be brought to bear on the deteriorating minute vessels in the deep, still living tissues, securing for them adequate protection by constantly maintaining the circulation at a high level, so as to prevent intravascular coagulation and hæmorrhage from extending into healthy tissues. Failing any way at the present time of attacking this, the central problem of the whole situation, the alternative is early surgical procedure which stops only where an efficient circulation is still maintained, and cuts off the products of the organisms from damaging fresh vascular areas and preparing fresh dead muscle for invasion. It would seem that the utility of free incision lies rather in the possibilities it offers for the avoidance of stagnation of the circulation, and in the relief of pressure, than in the hypothetical injury the admission of air to the tissues is supposed to inflict on the bacilli.

It appears clear that leucocytosis does not remain in abeyance only because of damage to veins, capillaries and blood ahead of the bacilli, but also because the products of the bacilli are repellent to leucocytes or do not incite leucocytosis. Where there is massive invasion there is a strong anti-chemiotactic action. In any case the contrast between the suppuration which pours out on incising ordinary purulent cellulitis or myositis, and the clear, œdematous, and cell-free, perhaps blood-stained, fluid of bacillary gangrene, emphasizes the great distinction between the parts played by the leucocytes in the two processes.

These are the conclusions I have arrived at on the basis of the admittedly imperfect number of examples I have studied in which bacillary invasion has advanced so far as to necessitate amputation of limbs. Only one instance has been quoted where the proximal end of a muscle could be left in a patient, and unfortunately it was not possible to examine what stayed the process; I cannot do more than hazard the inference that it was the efficient, perhaps engorged, circulation. An instance is quoted where the rapid provision of a collateral circulation saved both the arm and the life of the patient; the limitation of gangrene in segmental muscles points in the same direction. As yet I have not examined any long muscle in which the bacillary invasion has succumbed to the natural process of healing, although I have accumulated some material from animals for this purpose.

The time has surely come when we should unburden ourselves of the comforting reflection that the body has adequate powers of defence against virulent combinations of 'anaerobic' bacilli, and on the contrary bestir ourselves by serious systematic work in an endeavour to break a link in the fatal chain of events. A few weeks or a few months of concentrated effort may find that in the very complexity of the process lies its vulnerability to therapeutic attack.

The histological findings in the liver, adrenal, and thyroid glands, while suggestive, have not been sufficiently studied to warrant any expression of

opinion as to their probable significance. They merit, however, careful investigation, in view of the unaccountable collapse of patients whose wounds are doing well and would apparently have healed if the patient had survived. Their study might render it possible to tide over the period of danger, perhaps associated with a disturbance of the hormonal or autochoid mechanism lying at the basis of the sudden collapse of the cardiovascular and heat-regulating mechanism.

* * * * * *

Most of the illustrations have been made for me by Mr. J. R. Ford from the actual preparations, a few have been made by myself, and two specimens have been drawn by Mr. J. Thornton Shiells.

I desire to express my indebtedness to Major Sidney Rowland, with whom I was associated in the same laboratory for six weeks, and with whom I have had constant fruitful intercourse during this work. I have to thank him for providing me with a microtome and other indispensable apparatus, and with otherwise unprocurable staining reagents. Captain Harold Pringle collected many valuable pieces of tissue for me from autopsies. Captain Morrison has constantly brought to my notice all interesting surgical specimens coming under his observations. I am also indebted for much assistance to Lieutenant and Quartermaster H. J. Anderson.

Private T. C. Reynolds and Lance-Corporal N. Vidgen, my laboratory attendants, have sacrificed all their spare time to furtherance of this work, and deserve great credit for their share in it. To Sergeant Glover I am likewise indebted for his ever courteous and willing help.

In conclusion, it would not have been possible for me to carry out this work without the encouragement of Colonel H. E. Cree, Colonel C. E. Harrison, and Major W. J. P. Adye-Curran, under whom I have served in succession at the base, nor without the large number of animals which Dr. Roux, Director of the Pasteur Institute, generously presented to me, and the others purchased.

The expenses of this investigation have been paid by a grant from the Beit Memorial Fellowship Fund.

REFERENCES.

[1] BASHFORD, E. F., "Investigation of the Histology of the Tissues, Immediate and Remote from the Point of Injury, in Gunshot Wounds of the Liver, Spleen, Kidney, Intestine, Blood-vessels, Subcutaneous Tissue and Aponeurosis, and Muscles," *Brit. Jour. Surg.*, 1917, iv, No. 15, p. 433.

[2] WALLACE, C., *Brit. Med. Jour.*, 1916, ii, Sept. 16.

TWO CASES OF BULLET EXTRACTION FROM THE LUNG.

By R. LINDSAY REA, Belfast.

Case 1.

Sergt. R. was admitted to the Ulster Volunteer Force Hospital suffering from the effects of a bullet wound in the right side of the chest. He complained of stabbing pain beneath the right scapular region, with some coughing. *Fig.* 329 shows the direction of the wound, which at first was quite superficial, then became deeper, the bullet having travelled from the left shoulder downwards and to the right, evidently passing into the right thorax.

Two *x*-ray photographs were taken at right angles to each other, the one from side to side requiring 2 min. 15 sec. exposure, using a Macalaster-Wiggin tube with an accelerating screen. They revealed a bullet lying with its nose pointing backwards towards the wound. Either the bullet had caught on a rib just as it was spent, and had turned over, or it had entered with its flat face first. From the photograph (*Fig.* 330) it was difficult to say whether the bullet was in the liver, in the lung, or lying in the gutter formed by the pleura between the diaphragm and the ribs. The position was judged to be close to the 9th rib on the posterior axillary line.

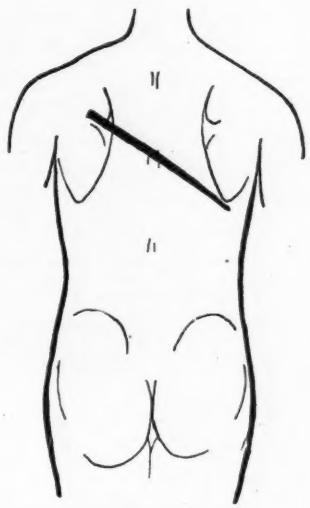


Fig. 329.—*Case* 1. Diagram showing the scar of the wound on the back.

Operation.—Mr. R. J. Johnstone, who performed the operation, resected a portion of the 9th rib where indicated, and on careful palpation found the bullet in the lung near its edge, with some adhesions holding the lung down to the diaphragm. Although chloroform was given, the movements of the mediastinum made it very difficult to steady the lung. Its edge was seized with a vulsellum, an incision made into it and, with very little hæmorrhage, the bullet was extracted. A small rubber drainage tube was left in the wound.

On the third day the tube was removed. There was no pus, and the patient's temperature soon became normal (*Fig.* 331). In three weeks the lung had re-expanded. The patient was discharged from hospital not long afterwards.

An examination of the bullet showed that its nose had been squeezed as if by pliers, possibly in an attempt to wrench it from its cartridge case in order to reverse it. As the ribs were not damaged, it is difficult to explain how it came to lie in the position indicated above.

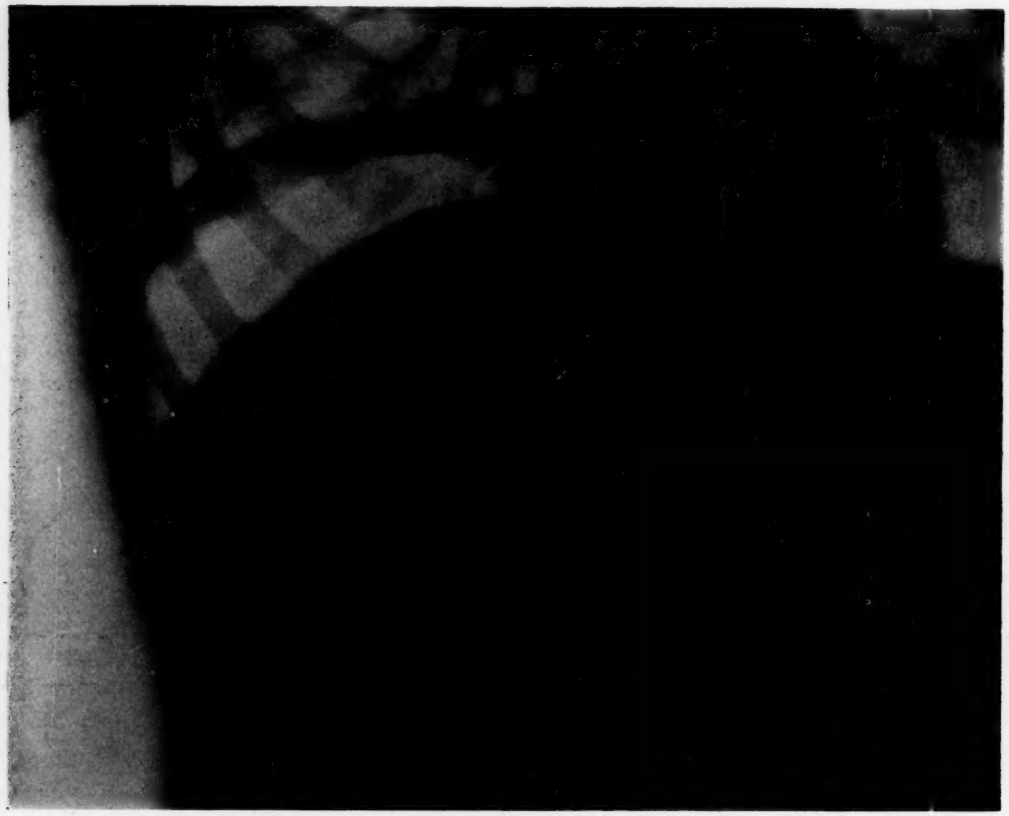


FIG. 330.—*Case* 1. *X*-ray photograph showing the position of the bullet close to the liver.

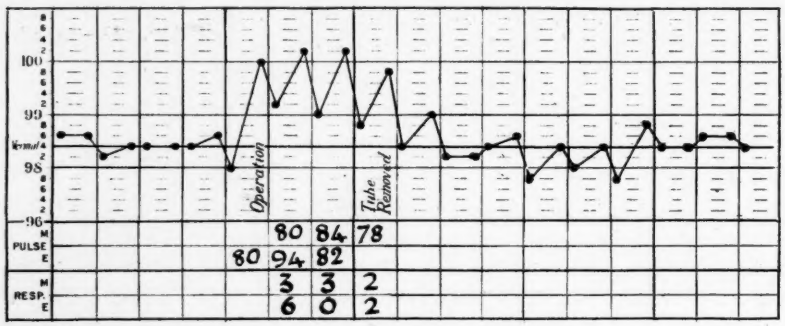


FIG. 331.—*Case* 1. Temperature chart

Case 2.

The *x*-ray work of this case was comparatively simple. With the screen, the bullet was easily seen lying in a vertical position behind the 1st intercostal space viewed from the front, and behind the cartilage of the 2nd rib, on the left side (***Fig.* 332**). By making the patient do a half right turn, and putting ink marks on the front of the chest and on the back in line with the bullet, then making him from this position do a left turn, and repeating the marks,

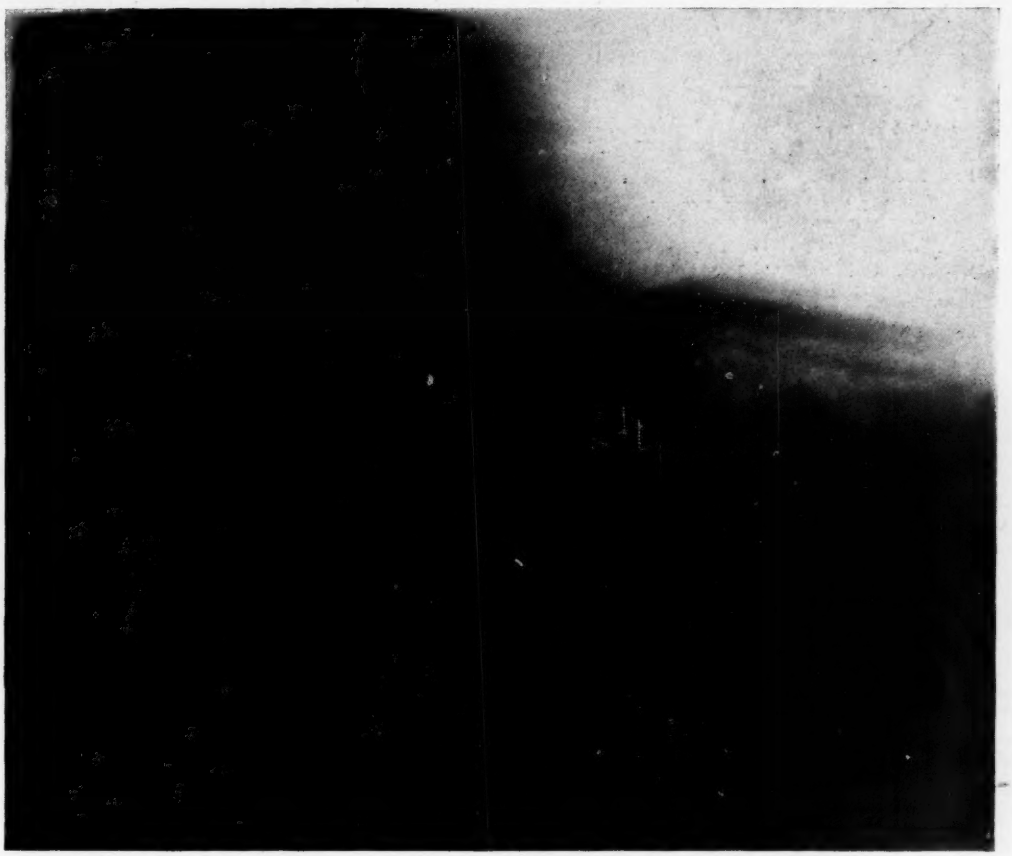


FIG. 332.—*Case* 2. *X*-ray photograph, showing the position of the bullet high up in the thorax.

two diagonals were indicated which, when drawn on a sketch of the horizontal section of the chest at this level, showed the point of intersection, and therefore the position of the bullet, to be almost half-way between the front of the chest and the back (***Fig.* 333**). By kind permission of Professor Symington, of the Anatomical Department, Queen's University, Belfast, a horizontal section of the thorax at the level of the cartilage of the 2nd rib was examined. The section is illustrated herewith (***Fig.* 334**). By careful examination and

measurement the bullet was judged to be lying in the upper lobe of the left lung, close to the mediastinum, and near to the left subclavian artery.

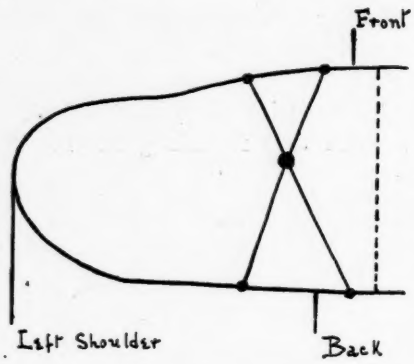


FIG 333.—*Case* 2. Sketch to demonstrate the use of diagonal lines.

Operation.—This was performed by Mr. Howard Stevenson. Chloroform being given by Dr. V. Fielden, the left arm was abducted from the side so as to put the fibres of the pectoralis major muscle in line with the 2nd rib. An incision was made, about five inches long, parallel to and over the 2nd rib, the muscle fibres were separated, and the 2nd rib with its cartilage was exposed. A portion about two and a half inches in length from the outer side of the internal mammary artery was removed, and the pleura opened. The lung did not rise to the wound as it usually does at first. The movements were excessive in this region, and for some time the bullet could not be felt. The upper lobe of the lung was found to be firmly held down by adhesions, and upon gently separating these, the apex was readily seized with broad prostatectomy

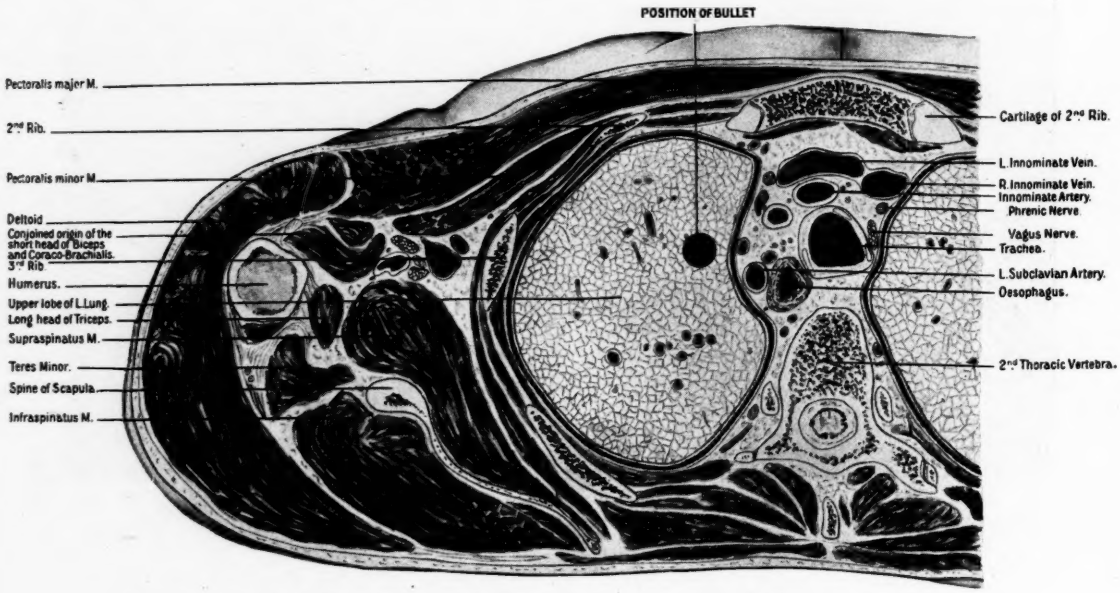


FIG. 334.—*Case* 2. Drawing to illustrate the position of the bullet. From a horizontal section of the thorax at the level of the cartilage of the 2nd rib.

forceps covered with indiarubber. The bullet was found exactly where indicated by the previous localization, and was removed through an incision made on the mediastinal aspect of the lung. In this case a drainage tube was not used.

There was a good deal of hæmorrhage, and the inevitable hæmothorax occurred, also considerable shock, and the patient's temperature (*Fig.* 335) did not settle down until almost a fortnight later. Vesicular breathing mixed with crepitations was heard at the end of three weeks, and a fortnight later the patient was able to move about.

Before taking *x*-ray photographs of the thorax, it is worth while spending a few minutes teaching the patient how to hold his breath for at least twenty seconds, and to hold it always in the position of full inspiration, so as to get a

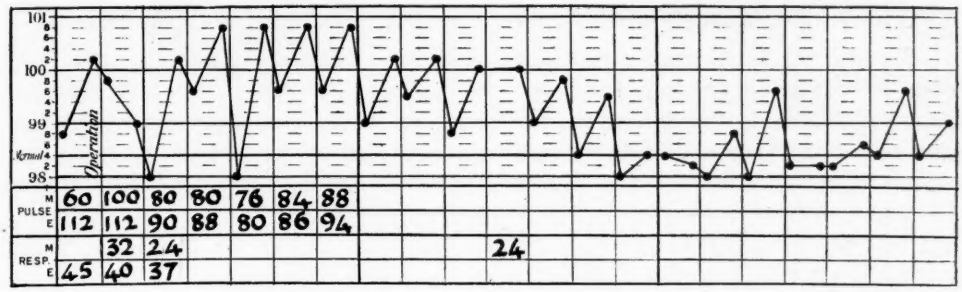


FIG. 335.—*Case* 2. Temperature chart.

clearer picture and one free from overlapping. The exposure in *Case* 2 consisted of two periods of 23 seconds each, using an accelerating screen.

It is impossible to overestimate the tremendous advantage of having at hand a series of horizontal sections, or drawings of horizontal sections, of the body, in order to examine the exact position of the foreign body and the best method of approaching it. The surgeon's task is made much easier by a previous examination of such specimens.

Fig. 334 was kindly drawn for me by Miss Rea, of the Anatomical Department, Queen's University, Belfast.

CASES OF INTEREST FROM THE NORTHUMBERLAND WAR HOSPITAL.

By Major C. D'OYLY GRANGE, R.A.M.C.

Case 1.—**Shrapnel Bullet in the Larynx. Removal by Thyrotomy.**

Sec.-Lieut. C. C. was wounded by two shrapnel bullets on July 1, 1916. One passed through the right side of his chest, entering at the second rib in front, and was buried in the region of the vertebral border of the scapula; the other entered his nose on the right side, passed through the hard palate, breaking away the two right incisor, the canine, and the first bicuspid teeth, and then passed into the tongue. For two days he lay in a captured German dug-out, without food or water, but apart from the blood about his mouth he suffered from no inconvenience in respiration.

An attempt was made in France to remove the bullet from the neck, but it could not be found. The bullet in the back was removed at this time. He was admitted to the Northumberland War Hospital on July 27, 1916.

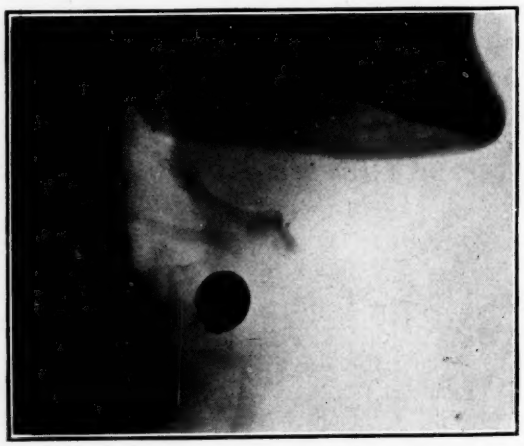


Fig. 336.—Shrapnel bullet in the larynx. The fracture of the hyoid bone and the small pieces of metal through the tongue can be seen.

A skiagram showed the shrapnel bullet to be lying immediately below the upper border of the thyroid cartilage, close to the middle line, on the right side. Its course through the tongue could be traced by marks left from small pieces of metal, and there was a fracture of the hyoid bone in the middle line (*Fig.* 336). Mr. Whillis examined the larynx, and reported that there was a swelling external to the false vocal cord which obscured the true vocal cord. From the skiagram and this examination it was evident that the shrapnel bullet was lying between the false cord and the thyroid cartilage on the right side, and that it had passed through the tongue and the hyoid bone without rupturing the mucous membrane of the larynx. His voice was rather husky.

Operation, Aug. 8, by Major C. D'Oyly Grange.—With the head quite straight, an incision was made in the middle line from the hyoid bone to the lower part of the thyroid isthmus. The isthmus was pulled downwards after dividing the pretracheal fascia, tracheotomy was done, and a piece of gauze

was packed into the trachea above the tracheotomy tube. The thyroid cartilage was fully exposed, with the cricothyroid membrane below and the thyrohyoid membrane above. A transverse opening was then made in the upper part of the cricothyroid membrane, and with a pair of sharp-pointed scissors, bent at an angle, the thyroid cartilage was divided in the middle line, the division being carried upwards to the cushion of the epiglottis. With blunt hooks the two alæ were separated, and a distinct bulge could be seen just above the false vocal cord. There was some hæmorrhage from the cut mucous membrane, but this was arrested by swabbing the surface with a 5 per cent solution of cocaine and applying gentle pressure. An incision parallel to and just above the false cord was then made over the swelling. The bullet was found embedded just under the mucous membrane, and with a pair of dissecting forceps it was easily removed. A small quantity of 'Bipp' was put into the cavity left by the bullet. By this time all bleeding had ceased, so the two thyroid alæ were brought together and accurately united by two catgut sutures, passed through the cartilage but not through the mucous membrane. The opening in the cricothyroid membrane was also sewn up. The gauze was removed from the trachea, but the tube was left in. A few sutures were used to bring together the sternohyoid muscles, and the upper part of the wound was closed.

The patient suffered no inconvenience from the anæsthetic. The tracheotomy tube was removed on the fourth day, and the wound soon closed. At first there was a good deal of pain in swallowing, but this passed off. For four weeks the patient was not allowed to speak above a whisper, after which he began to speak in the ordinary way.

Six weeks after the operation his voice was as good as it was before the bullet was removed. Examination of the larynx on Nov. 8 (three months after the operation) showed that there was still some œdema of the right side. [*Ref. No.* 196.]

Case 2.—**Aneurysm of the Axillary Artery following a Bullet Wound of the Shoulder.**

Pte. T. M. was admitted to the Hospital on July 15, 1916, having been wounded on July 10.

On admission, there was a small hole about two inches below the tip of the coracoid process of the right scapula, and a rather larger wound on the back, close to the axillary border of the bone. A skiagram showed that a small piece had been chipped off the scapula in this position. Patient stated that when he was hit there was considerable hæmorrhage from the anterior wound, but this was stopped by the field dressing. He had complete paralysis of his arm from the time he was wounded.

The anterior wound healed up completely, but on Aug. 5 it was found that he had a swelling in the axilla. This bulged the anterior wall forward, and pulsated distinctly. There was no pulse at the wrist on the same side. The swelling increased in size rapidly, and by Aug. 10 he complained of considerable pain in the shoulder and arm. There was a very marked bruit over the swelling.

Operation, Aug. 11.—An incision was made along the clavicle from

near its inner end outwards to the coracoid process, and then downwards across the anterior axillary wall and along the inner side of the arm. The shoulder was pressed upwards by the aneurysm, and it would have been difficult to reach the subclavian artery in the ordinary way, so an inch and a half of the middle of the clavicle was sawn out after drilling holes through it for sutures later. This piece of bone was kept in warm saline during the operation. The subclavian artery was isolated in its third part, and a ligature of thick silk was passed round it, but not tied. The brachial artery was then exposed just below the axilla, and a similar piece of silk was passed round it. The pectoralis major muscle was next divided transversely and reflected. The pectoralis minor muscle had been so much destroyed as to be almost non-existent in the upper part, and the sac of the aneurysm could be seen underneath it, with a few fibres of muscle stretched over it. In cutting through these fibres, the sac, which was extremely thin, was opened, and there was an immediate gush of blood. This was controlled easily by pulling upon the silk ligature around the subclavian artery. The sac was now fully opened up, and the axillary artery could be seen at the back of the aneurysm. There was a hole in it three-quarters of an inch long, involving half the circumference of the vessel in its second part. A small quantity of blood was coming from each end, more particularly the lower. The artery was then dissected free, and a catgut ligature was passed around it above and below, and tied. None of the nerves of the brachial plexus were seen, owing to the amount of organized clot around the artery. On releasing the ligature on the subclavian there was no bleeding from the vessel, but considerable oozing from all the divided tissues. The divided pectoralis major muscle was now repaired with thick mattress catgut sutures, and the piece of clavicle which was excised was put back in place and held by catgut sutures passed through the holes previously bored. The skin was sewn up, and a drainage tube inserted at the lower end of the wound. The exit wound of the bullet was then examined, and a bony sequestrum of the scapula was removed from it.

The wound was dressed next day, owing to the amount of oozing, and on the third day the tube was removed. The wound healed by first intention, and four weeks later the patient was able to move his hand slightly. Unfortunately the portion of clavicle excised and replaced was not held by the catgut sutures long enough in position; it became displaced, so that the piece lay obliquely across the gap. Bony union however, was excellent; but the clavicle as a result is rather shorter than that of the other side. The pectoralis major healed, and the upper part contracts well, but the lower fibres are still paralyzed. The hand now (Nov. 8) still gets very cold if exposed. The radial pulse has not yet returned. The power of flexion of the wrist and fingers has returned, but at present he has no power of extension. [*Ref. No.* 197.]

Case 3.—**Diaphragmatic Hernia following a Bullet Wound.**

Pte. S. R., age 39, was wounded by a rifle bullet on March 4, 1915, while laying wire entanglements. The bullet entered the left side of his back just below the 12th rib, three inches from the middle line, and emerged below the 7th rib, one and a half inches outside the nipple line, on the same side.

He was sent to a hospital in Scotland, where he stayed from March 17 to May 17, during which time the wounds healed, with few symptoms; he states that he expectorated some blood, but had no gastric trouble. He returned to France at the end of June, but as he felt pain in the left side after marching, he was sent to hospital, and arrived here on July 10. He complained of pain in his left side after exertion, but the examination showed nothing abnormal except a few râles at both bases.

On July 19 he was seized with sudden pain in the upper part of the abdomen. He had no vomiting. His bowels were slightly moved by an enema on the following day. When seen on July 23 he had vomited. He had had no passage of fæces or flatus since July 20. On examination of the abdomen it was seen to be hollow, and except for this nothing abnormal was found. On examining the chest, it was noticed that there was a large tympanitic area on the left side, but a diagnosis of the cause of the obstruction was not made. The stomach was washed out, and as it contained a quantity of intestinal contents an operation was undertaken at once.

Operation.—The abdomen was opened by a long middle-line incision with excision of the umbilicus, and the first thing noticed was that there was very little visible omentum. The cæcum was first examined, and found to be moderately distended, but the ileum was contracted and empty. It was now thought that the obstruction was above this, so the whole length of the small intestine was examined, without revealing any obstruction.

The large intestine was next examined, and it was seen that the transverse colon was extremely short, but it appeared to pass into the descending colon all right. On further examination of the splenic flexure, however, one found that there was a hole in the diaphragm, and that some of the gut had passed through this aperture. A finger was passed through, and the hole enlarged with scissors. Gentle traction was applied to the gut, and out came the transverse colon, enormously distended, and the greater part of the omentum. This distended gut formed a formidable obstacle to reaching the rent in the diaphragm, so an œsophagus tube was passed into the rectum, and by manipulation some of the gas was passed on. The gut was fortunately perfectly healthy. The hole in the diaphragm could now be seen just in front of the spleen, and easily admitted my hand. It was a case of false hernia, as there was no sac. The edges of the opening were quite smooth, and one could see the lung clearly. It was completely collapsed, and there were no adhesions. At each breath air rushed in and out of the pleura through the aperture, and the diaphragmatic edges flapped about.

An attempt was now made to suture the rent, but this was extremely difficult owing to the depth of the cavity and the movements of the diaphragm, and also the fact that our supply of needles and instruments was distinctly limited, the hospital having been opened only a short time. After several attempts, three sutures of thick catgut were passed across the hole, and by the aid of catch forceps applied to the edges to approximate them, the sutures were tied, and the hole almost closed except for a small part at the outer side. An attempt was made to stitch the spleen over the rent, but the sutures would not hold. This small aperture was finally left, as the patient was by this time in a collapsed condition. The intestines were then replaced, which was

no easy matter, owing to their distended state. The abdominal wall was sutured in one layer of through-and-through silk sutures. Two pints of normal saline were given intravenously, as the patient was very collapsed, the operation having taken two hours.

For the first three days he was in a critical condition, and suffered considerably from 'wind.' This was relieved by the use of the rectal tube and turpentine enemata. The wound healed well and the patient made a complete recovery. There were no chest complications. He was examined with the *x* rays in September. The left side of the diaphragm could be seen to move downwards less well than the right, and a part of it appeared to be adherent to the ribs; but this caused him no disability, and he was discharged for light duty. His abdominal viscera were no longer in his thorax, and his lung had completely expanded. [*Ref. No.* 198.]

Siebert[1] records a case on which he operated successfully, where the stomach had passed through a hole in the diaphragm; at the operation this hole was found to be the œsophageal aperture considerably enlarged. He gives a review of the literature on diaphragmatic hernia, in which one sees that two cases of cure by the thoracic route[2] have been recorded, and two of cure by the abdominal route. One of these, operated on by D. C. Balfour[3] at the Mayo Clinic, was caused by trauma four years previously; in this case there was a hole in the left side of the diaphragm which allowed of protrusion of the stomach and bowel into the chest cavity, with displacement of the heart and lungs.

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NOTES ON FIFTY CASES OF INJURY OF THE PERIPHERAL NERVES.

By Captain J. RENFREW WHITE, R.A.M.C.

Before the war cases of nerve injury were of rare appearance, except to the specialist; now they are being produced in considerable numbers, and are become to medical men engaged in treatment of the wounded a daily occurrence and a subject of great importance in diagnosis and treatment.

One result of the greatly increased amount of material now available for study will be an extension of the pre-war limits of theoretical knowledge, and a modification of former rules of treatment.

This account of fifty cases of injury of the peripheral nerve trunks—the great majority being the result directly or indirectly of gunshot wounds—does not concern itself with such a complete story of the whole series of clinical and pathological phenomena as only a great deal of time and continuous observation, from the period of infliction of the injury to the termination in partial or complete recovery, would render possible. Under the conditions of war and active service neither such time nor such opportunity of observation has been at the writer's disposal; what he aims at, therefore, is an account of the detailed clinical examination of the cases, combined and compared with the operative findings in many instances, with the object of gaining a better knowledge of the phenomena such injuries produce, and thus ensuring greater accuracy of diagnosis and more skilful and efficient treatment.

Relative Frequency of Injury of the different Peripheral Nerves.—The following table shows the actual and relative frequency of injury of the different peripheral nerves in this series:—

	Times Injured	Per Cent
Ulnar nerve	16	24·6
Musculospiral nerve and branches	11	17
Great sciatic nerve and branches	11	17
Median nerve	7	10·8
Brachial plexus	7	10·8
Internal cutaneous nerve	6	9·2
Musculocutaneous nerve (arm)	3	4·6
Cauda equina	2	3
Spinal accessory nerve	1	1·5
Cervical plexus (great auricular and small occipital nerves)	1	1·5

ROUTINE OF EXAMINATION.

A routine examination for the following signs and symptoms has been carried out in each case:—

1. Signs rapidly and easily noticed or elicited that suggest the presence of nerve injury.

a. The presence of muscular wasting, as compared with the opposite side.

b. Abnormal position of a limb or segment of a limb, such as main-en-griffe, drop-wrist, genu valgum, and various forms of talipes. Such position may be due to one or more of the following factors: action of gravity, contraction or contracture of unparalyzed antagonistic muscles, contracture of scar tissue, contracture due to myositis of traumatic, septic, or ischæmic origin—the two last being independent of the actual nerve injury, but due to the same cause, viz., the entrance of the foreign body.

c. Abnormal limitation of mobility of joints, due to conditions similar to those causing abnormal position of a limb.

d. Presence of tenderness along the course of nerve trunks.

2. Signs and symptoms that require longer and more careful investigation, and that directly result from the cessation or diminution of the passage of impulses, afferent and efferent, along the nerve trunk.

Afferent (Sensory) Changes (tested with the eyes bandaged).

a. Epicritic sensibility, tested by light cotton-wool strokings that cause no deformation of the surface of the skin, after shaving the suspected area.

b. Protopathic sensibility, tested with pin-pricks: the presence of an area in which it is lost or increased (hyperalgesia).

c. The relation in size and position of the areas of loss in (a) and (b).

d. Deep sensibility, tested by deep pressure: the area of its loss.

e. The presence or absence of joint sense.

f. The presence or absence of shooting pains and paræsthesiæ: their distribution.

Efferent Changes.

a. The determination of the presence or absence of voluntary contraction of individual muscles: by actually watching or feeling the suspected muscles contract or harden, a much less fallacious method than merely testing the power to perform specified movements of joints.

b. The determination of the presence or absence of involuntary contraction of unstriped muscle: by noting such points as local cyanosis of a paralyzed part due to vasomotor paralysis; pupillary changes in lesions of the third, sympathetic, and first dorsal nerves; pilomotor paralysis; bladder and rectal disturbances.

c. Secretory changes: increase or decrease in the secretion of sweat. Very often the area of cutaneous sensory loss may be estimated at a glance as corresponding fairly closely with the area of dryness of the skin supplied by the affected nerve. In cases of causalgia or incomplete physiological lesion, this area will often show increased sweating.

d. Trophic changes: trophic ulcers and blisters; wasting of finger-pulps; presence of delayed desquamation over the area of sensory loss, often showing the boundaries of this area at a glance.

e. Changes in the electrical reaction of the paralyzed muscles: (i) their

reaction to faradism; (ii) their reaction to galvanism, especially noting the relation between kathodal closing stimulation and anodal closing stimulation, and the character of the consequent contraction.

COMPLETENESS AND INCOMPLETENESS OF NERVE LESIONS, AND THEIR DIFFERENTIATION.

(With reference chiefly to Lesions caused by Gunshot Wounds and their Sequelæ.)

The question of the completeness or incompleteness of any particular lesion is one of the greatest importance in its bearing on prognosis and treatment.

A lesion is *pathologically* complete when no impulses pass it in either direction. As we shall see later, however, before and even at operation it is often difficult or impossible to be certain that such a condition of absolute failure of conduction exists. In our present state of ignorance, we have often to fall back on a compromise of *clinical* completeness.

1. **Pathological Completeness.**—This may be (*a*) anatomical, (*b*) physiological, or (*c*) a combination of the two.

a. Anatomical.—There is actual interruption of physical continuity of the nerve trunk, the foreign body or piece of fractured bone having actually cut through the nerve completely. At operation, both ends will be found separated, swollen, and bulbous, lying usually in an adherent mass of scar tissue.

b. Physiological.—Here there is no such physical discontinuity, but complete interruption of conduction. This may be due to one or more of the following pathological conditions, all of which, with one exception, are recognizable at operation—

i. 'Compression from without,' by foreign body, piece of fractured bone, hæmorrhagic extravasation, inflammatory exudation, masses or bands of scar tissue and callus, etc.

ii. 'Compression from within,' as in bruising and interstitial neuritis—i.e., pressure on the individual bundles of fibres by blood or inflammatory exudates between the bundles and fibres themselves. When such extravasated blood or exudation becomes organized, the typical spindle swelling is the result. The same process produces the bulbous ends of amputation neuromata or of accidentally divided nerves.

iii. Such damage to the nerve, without actual physical solution of continuity, as has led to complete fibrosis of its cross-section.

iv. Involvement of the nerve in an area of local ischæmia, as in Volkmann's paralysis.

v. 'Concussion' of the nerve trunk, without macroscopic lesion, a condition about which little is so far known, but which apparently interferes with conduction.

c. Combined Anatomical and Physiological.—This is possible, and chiefly occurs in lesions of the cauda equina, brachial plexus, and, most typically, the great sciatic nerve. In the case of the last, part of the nerve is anatomically divided, and the remainder involved in one of the pathological processes just mentioned as causing physiological complete division. It is obvious that

this state of affairs is very much more likely to occur with large than with small nerve trunks.

2. **Pathological Incompleteness.**—This may be of any degree, from the slightest diminution, to almost complete cessation of conduction of impulses—pathological completeness—and associated with clinical signs from the slightest, up to those falling just short of clinical completeness. It may be (*a*) anatomical, or (*b*) physiological.

a. Anatomical.—This occurs chiefly with large nerves. Here part of the nerve is anatomically divided, but the rest conducts a certain number of impulses. This condition is most commonly met with in the case of the great sciatic. The rest of the nerve in most of the cases is the seat of an incomplete physiological lesion; hence this variety might be called 'combined anatomical and physiological incompleteness.'

b. Physiological.—This is the most common pathological condition found in such cases; it is due to a lesser degree of the conditions enumerated above as causing physiological completeness. In these conditions the pathological process may in many cases affect more or less uniformly the whole cross-section of the nerve trunk; in others it may constitute a complete lesion of a part of the cross-section—often (as in *Cases* 28 and 41) of a part clinically recognizable as supplying certain definite muscles with motor power, or definite tissues and areas with sensibility. The rest of the cross-section may or may not be the seat of an incomplete lesion. When it is so, the condition might then be called 'combined physiological completeness and incompleteness.'

RELATION BETWEEN CLINICAL SIGNS AND SYMPTOMS AND THE COMPLETENESS OF THE LESION.

1. **The Clinical Signs and Symptoms of a Complete Lesion.**—With a pathologically complete lesion one expects to find the following cardinal and classical signs of complete failure of conduction: (*a*) Absolute loss of voluntary and involuntary motor power in muscles exclusively supplied by the affected nerve distal to the lesion; (*b*) No reaction of such muscles to faradic stimulation; (*c*) The typical reaction of degeneration on galvanic stimulation; (*d*) The full loss of sensibilities, epicritic, protopathic, and deep, over the recognized areas peculiar to each nerve. We shall see, however, that insistence on the fulfilment of these four conditions in every case before the diagnosis of a complete lesion is considered as established, will result in discrepancies between the condition diagnosed and the condition found at operation, or between the prognosis considered justifiable and the actual amount of recovery obtained. Hence it is important that one should study each of these signs as regards its relation to completeness of failure of conduction. It is mainly in regard to the last two that difficulties arise.

a. Absolute Loss of Voluntary Motor Power.—This is of course a *sine qua non* of the diagnosis of a complete lesion. Anatomical irregularities of nerve supply to muscles, such as that which occurs in *Case* 20, must, however, be kept in mind; otherwise one may be led astray.

b. The Absence of Response to Faradic Stimulation.—Irregularity of nerve supply must also be borne in mind here. In most cases a muscle that will not

react to faradism cannot be voluntarily contracted; but this is not invariable (see *Case* 32).

c. The Character of the Response to Galvanism.—It was formerly considered that on complete division of a motor nerve the muscles exclusively supplied by it developed within a short period the typical 'reaction of degeneration'—i.e., (1) A stronger galvanic current is needed to elicit contraction than on the sound side; (2) The contraction so elicited is peculiarly sluggish in character; (3) The anodal closing response is greater than the kathodal closing response.

That a stronger current is necessary is true; that the responding contraction is often, but not always, sluggish in character is also true; but with the fuller experience of the present day, it appears to be more than extremely doubtful whether we can any longer rely on the relationship between the results of anodal and kathodal stimulation as an absolute index of completeness of division. In the present series, the writer has found not only complete anatomical division without the development of this reaction, but also the converse condition—viz., full 'reaction of degeneration' in a muscle capable of voluntary contraction. The following classification summarizes the various cases of this series with regard to this point—

i. A.C.C. greater than K.C.C. in the paralyzed muscles:—

In 1 case (29), at operation, complete anatomical division.

In 4 cases (10, 35, 37, 47), no operation performed, but everything—e.g., the position and size of the wounds—pointed to complete anatomical division.

In 1 case (13), at operation, complete fibrosis of the nerve.

In 1 case (28), the muscle reacted to faradism.

In 1 case (32), the muscle did not react to faradism, but contracted voluntarily.

ii. K.C.C. greater than A.C.C. in the paralyzed muscles:—

In 1 case (11), at operation, complete anatomical division.

In 2 cases (18, 46), no operation, but everything pointed to complete anatomical division.

In 5 cases (9, 19, 20, 40, 43), at operation, complete fibrosis.

In 8 cases (24, 25, 26, 27, 30, 33, 44, 45), incomplete division.

In 2 cases (16, 20), at operation, complete fibrosis; nerve resected and sutured; at post-operative examination, K.C.C. still greater than A.C.C.

In 1 case (25), at operation, complete fibrosis; nerve resected; at post-operative examination, A.C.C. now greater than K.C.C.

iii. K.C.C. greater than A.C.C. in one set of paralyzed muscles, A.C.C. greater than K.C.C. in another set:—

In 1 case (20), at operation, complete fibrosis; nerve resected; post-operative examination showed the same state of affairs.

In 2 cases (15, 41), there was 'compression from without' found at operation.

It is impossible from this analysis and classification to formulate any theory as to the actual pathological basis of the reaction of degeneration; nor does it seem to the writer any longer possible to depend on the presence or absence of such a reaction as a guide in the diagnosis of completeness or incompleteness. In our ignorance then of the significance of this reaction, it would seem that we must adopt the phrase 'clinical completeness' in cases where all the classical signs of pathological completeness are present except the full reaction of degeneration.

d. Full Loss of the Various Forms of Sensibility.—The knowledge of what constitutes the full loss in each particular case cannot be gained from text-books of anatomy or from anatomical dissections, but will come only by study of many cases of actual nerve injury. In the case of most nerves, however, it bears a fairly constant relationship to the anatomical area of supply; nerves which are striking and often puzzling exceptions are the musculospiral and the upper roots of the brachial plexus. Concomitant injury of muscle and tendon modifies greatly the extent of loss of deep sensibility.

2. **The Clinical Signs and Symptoms of an Incomplete Lesion.**—Whilst the clinical signs of a complete lesion of a particular nerve at a particular level vary in different cases not at all, or at most only in very small details, different cases of incomplete lesions of the same nerve vary enormously in their clinical signs according to the nature and severity of the lesion in each case. Generally speaking, however, one may say that a definite order is recognizable in which, as a slight clinically incomplete lesion progresses more and more towards clinical completeness, the signs of this change appear. Those cases in which the first only of these signs appears—no matter how slight or great the extent of the area of the loss—are instances of slight incomplete lesions; those in which the more advanced clinical stages are present as well—even if not in a marked or full degree—are instances of much severer incomplete lesions.

In some cases, however—and this specially often occurs with the larger nerve trunks—where the block of conduction is not uniformly distributed throughout the whole thickness of the nerve at the level of the lesion, or indeed only affects one part of the cross-section of the nerve, it is possible for certain of the later advanced stages, e.g., loss of voluntary motor power or loss of faradic response, to be present in the absence of some of the earlier stages. *Case* 41, a lesion of the great sciatic, is a good instance of this. In it loss of epicritic sensibility is very small in extent, loss of protopathic quite absent; yet there is full loss of voluntary motor power and faradic response below the knee, and indeed in one set of muscles full reaction of degeneration exhibited on galvanic stimulation. In such a case one can be sure that the lesion, of course incomplete, is not uniformly distributed throughout the thickness of the nerve. It should be contrasted with *Case* 45, where an obviously incomplete lesion of the same nerve shows the typical gradation of clinical signs—full loss of epicritic sensibility, full loss of protopathic, retention of motor power except in the peronei, which alone fail to respond to faradism. Here the pathological process constituting the lesion—one can be sure—is of a slighter degree, but of a more uniform distribution.

This order, of course, holds good only with mixed nerves, and does not apply to such mixed nerves as have no exclusive area of sensory supply—e.g., the anterior primary division of the fifth cervical. The order is as follows :—

a. Loss of Epicritic Sensibility.—In the cases of least severity, this area falls short of that characteristic of a complete lesion. The slightest degree of its loss is manifested by inability to distinguish the number of points of a compass, and to localize a point stimulated by light touch.

b. Loss of Protopathic Sensibility.—This is a further stage along the road to completeness. Here again—but to a less extent, for protopathic loss is far more variable even in complete division in different cases of the same nerve lesion—the extent of the area of its loss is proportional to the degree of completeness.

c. Loss of Motor Power.—This may vary from mere weakness of some of the muscles, to complete loss of voluntary power of a group or of all of the muscles exclusively supplied by the nerve.

d. Loss of Response to Faradism.—In some or all of the above-mentioned muscles this occurs. It is not, however, an invariable rule that a muscle which fails to respond to faradism fails of voluntary contraction (see *Case* 36).

Other signs which are characteristic of incomplete division, and in most cases pathognomonic of it, are:

i. The presence of sweating—often excessive—over the area of exclusive cutaneous supply.

ii. The presence of shooting pains and paræsthesiæ referred to the area of supply of the nerve distal to the lesion. On the other hand, the eliciting of pains or paræsthesiæ referred distalwards, by pressure over the seat of nerve injury, does not necessarily mean an incomplete lesion, as these are often due to pressure over a part of the nerve just proximal to the lesion, which is the seat of an interstitial neuritis, and in such a case are analogous to those occurring on pressure over an amputation neuroma.

iii. Tenderness of the nerve trunk below the lesion, or the production of paræsthesiæ by pressure on the nerve below the lesion.

iv. Certain trophic changes in the skin—glossiness, redness, and blisters; of course the last are not by any means pathognomonic of incompleteness.

v. Hyperalgesia of the skin exclusively supplied, without protopathic loss.

vi. A patient with an incomplete division which is causing much pain frequently gets into a very emotional and hysterical condition, and will become very antagonistic at the suggestion of another sensory examination. This was so with *Case* 44.

vii. The nature of the galvanic response: Sherren has described a reaction of incomplete degeneration which sometimes occurs with an incomplete lesion. The paralyzed muscle will respond by contraction to a smaller current than on the opposite side; usually the polar reversal is absent. The diagnostic value of an absent reaction is slight.

PARTICULARS OF CASES.

CRANIAL NERVES AND CERVICAL PLEXUS.

The only case of injury to a cranial nerve in this series, the spinal accessory, is also the only case of injury to branches of the cervical plexus.

Case 1.—**Division of the Small Occipital and Great Auricular Nerves, with subsequent involvement of the Spinal Accessory as it enters the Posterior Triangle of the Neck.**

Pte. H., age 31, was wounded Sept. 3, 1916, by a piece of shell in the left side of the neck. It entered at the posterior edge of the sternomastoid, and came out in the mid-line in front of the trachea, a suppurating track resulting.

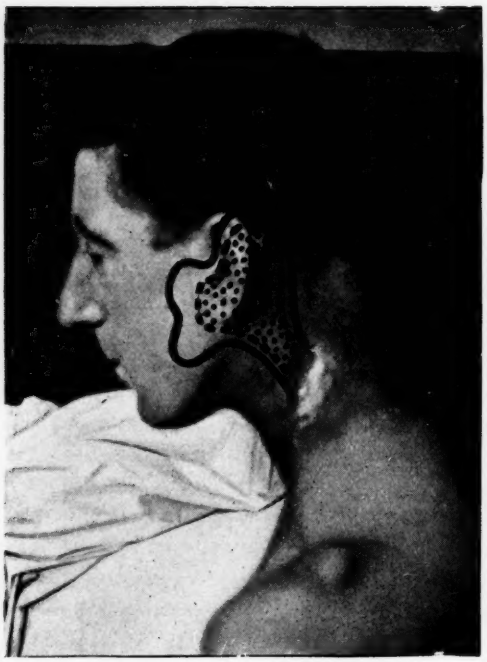

FIG. 337.—*Case* 1.—Division of the small occipital and great auricular nerves, showing areas of epicritic and protopathic loss.*

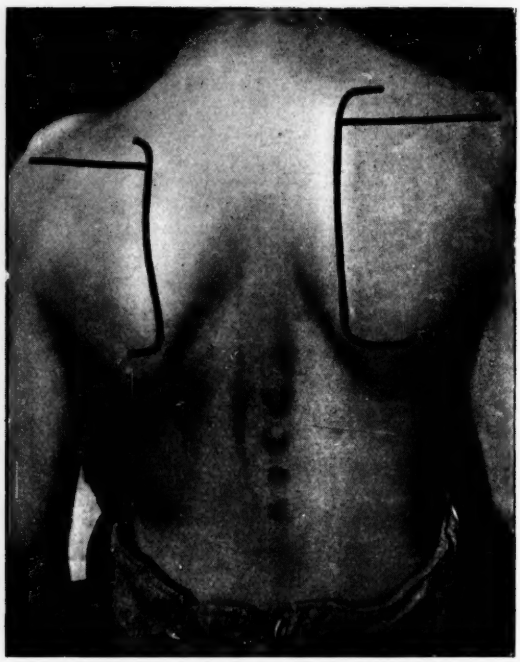

FIG. 338.—*Case* 1.—Incomplete division of the left spinal accessory nerve, showing the dropping of the scapula and the wasting of the trapezius muscle.

ON EXAMINATION, Sept. 16.—There were areas of sensory loss as in *Fig.* 337. No shooting pains or paræsthesiæ. The numbness was noticed immediately after being wounded.

Oct. 10.—The spinal accessory nerve has become involved lately in the scar tissue. There is great wasting of the whole trapezius and dropping of the scapula. There is voluntary contraction of the levator anguli scapulæ and sternomastoid muscles, but none of the trapezius. With faradism the lower fibres only of the trapezius contract, whilst on stimulation of the upper fibres of the opposite trapezius with the kathode, this part of both muscles contracts. *Fig.* 338 shows the wasting of the trapezius and the dropping of the scapula.

* In all the figures, a thick line shows the margin of epicritic loss, a broken line that of protopathic loss, and a thin line that of deep loss (area horizontally shaded).

BRACHIAL PLEXUS.

Seven cases occur in the series; four are due to gunshot wounds, and the remaining three are examples of subcutaneous injuries of nerves.

Lesions of the brachial plexus are theoretically capable of displaying an almost unlimited variety of clinical pictures; but actually we find that a certain few of these pictures appear and reappear very many times more frequently than do others. Lesions of the main trunks, apart from branches, fall naturally into the following classification :—

1. Lesions of the whole plexus, complete or incomplete, usually the latter.
2. Lesions of one or more of the anterior primary divisions from C.5 to D.1 inclusive: (*a*) Lesions of the upper divisions—Erb-Duchenne type (see *Cases* 2, 3, and 4); (*b*) Lesions of the lower divisions—Klumpke type (see *Cases* 5 and 6).
3. Lesions of one or more of the trunks: (*a*) The upper trunk—also Erb-Duchenne type; (*b*) The middle trunk; (*c*) The lower trunk.
4. Lesions of one or more of the cords: (*a*) The outer cord (see *Case* 7); (*b*) The posterior cord; (*c*) The inner cord (see *Case* 8).

Upper Arm, or Erb-Duchenne, type of Lesion.—As was the case with subcutaneous injuries due to indirect violence before the war, so it would appear to be now with direct gunshot injuries and their results—the most common type of brachial plexus paralysis is the Erb-Duchenne. This type follows lesions of either the fifth cervical anterior primary division, the sixth cervical, or of the upper trunk. In subcutaneous and especially in obstetrical cases, it seems to be the fifth cervical root that is the seat of the lesion, in some cases possibly the fifth and sixth. Sherren has shown, however, that the addition of the sixth anterior primary division adds no further motor disability; indeed, that stimulation of this root alone causes contraction merely of the clavicular head of the pectoralis major and sometimes a feeble contraction of the triceps.

All observers since Duchenne are agreed that a pure lesion of the fifth cervical anterior division produces no loss of cutaneous sensibility; *Cases* 2 and 3 are examples of this. Even with simultaneous division of the fifth and sixth anterior divisions, or of the upper trunk, no appreciable sensory loss may result; but more often this is not so, and a sensory loss occurs, which is evident in the earlier state of *Case* 3 and in *Case* 4. In this latter case, however, the sensory loss is of such a peculiar character as will necessitate special discussion later.

Apparently, then, the fifth cervical anterior primary division is chiefly motor, and has no exclusive area of sensory supply; whilst the sixth has little if any exclusive motor supply, but usually at any rate definite areas of exclusive sensory supply. These deductions are fully borne out by *Cases* 2 and 3. In *Case* 2, with a lesion evidently of the fifth root, there was no sensory, but full motor loss. In *Case* 3, there had been areas of sensory loss on the radial side of the hand and over the insertion of the deltoid, but by the time of examination these had disappeared, though pressure over the scar produced paræsthesiæ in the former area; motor loss was that of the fifth cervical anterior primary division. Operation showed a complete anatomical division

of the fifth root, with slight compression of that part of the upper trunk made up of the fibres of the sixth anterior primary division. The evidence supplied by *Case* 4, although in it the character of the sensory loss is anomalous, tends in the same direction.

Case 2.—Pte. G. was wounded Oct. 21, 1914, in the right scapular region by a rifle bullet which fractured the upper part of the scapula and entered the neck. The wound suppurated. Paralysis of the right arm was noticed immediately.

On Examination, March 18, 1915.—

Position of Limb, etc.—Arm hangs limp by side; elbow extended; full pronation. Wasting of deltoid, biceps, brachialis anticus. The head of the humerus is fallen from its bony socket.

Sensation.—Percussion of a hard indurated mass in the supraclavicular region causes tingling in the hand. No sensory loss.

Motor Powers and Loss.—Voluntary contraction of the rhomboids and all muscles of the limb except deltoid, b ceps, brachialis anticus, supinators, and spinati.

Diagnosis.—Lesion of the fifth cervical anterior primary division. distal to the point of origin of the nerve to the rhomboids. From the absence of sensory loss, probably the sixth root and the upper trunk have escaped—so far as not to have produced sensory loss.

Case 3.—This was an exactly similar case to the last, except that the rhomboids also were paralyzed, and that there had been some sensory loss in the thumb and radial side of the hand and also over the insertion of the deltoid.

Pte. B., age 23, was wounded on right side of neck by pieces of shell on July 4, 1916. There were entrance and exit wounds. He noticed the paralysis at once.

On Examination, Sept. 14.—The wounds were healed.

Position of Limb, etc.—All muscles of upper extremity weak and wasted. Complete slight main-en-griffe.

Sensation.—No perceptible sensory loss, but patient volunteered that at first he had numbness over the deltoid insertion and on radial side of hand. He has lately had paræsthesiæ in the latter position; these can now be induced by pressure over the scar; hyperalgesia in above areas.

Motor Powers and Loss.—Voluntary contraction of all muscles except biceps, brachialis anticus, deltoid, spinati, rhomboids, supinators, and part of pectoralis major.

Electrical Reactions.—All these muscles fail to respond to faradism. To galvanism: rhomboids, K.C.C. greater than A.C.C.; deltoid, A.C.C. greater than K.C.C.

Diagnosis.—Clinically complete division of fifth cervical root, with an incomplete recovering lesion of sixth cervical root or of part of the upper trunk.

Operation, Oct. 20.—The upper trunk was surrounded by scar tissue, with no trace of the fifth cervical root proximal to it; the suprascapular nerve was found divided from it, and no sign of the nerve to the rhomboids.

Case 4, which follows, on its motor side exactly resembles *Cases* 2 and 3, and is typical of a lesion of the fifth cervical anterior primary division. On its sensory side, however, it shows—what is in the case of lesions of the peripheral nerves an almost unique phenomenon—dissociation of cutaneous sensibilities; this obscures the diagnosis, and raises, if it does not throw definite light on, important questions as to the sensory supply of these anterior primary divisions.

Case 4.—T. B., age 8, was reported by her mother to have had a paralyzed right arm from birth.

On Examination.—

Motor Loss and Powers.—Voluntary contraction of all muscles of right upper limb except biceps, brachialis anticus, deltoid, and supinators.

Sensation.—As in *Fig.* 339.

DIAGNOSIS.—The history, appearance of the limb, and the distribution of the motor loss obviously point to a diagnosis of obstetrical paralysis of the Erb-Duchenne type; the absence of paralysis of the rhomboids and spinati, and the presence of sensory loss would seem to point to the upper trunk as being the site of the lesion. When however we come to consider the character of this sensory loss, we see at once that difficulties arise as to the diagnosis. In such cases of lesions of the upper trunk which exhibit sensory loss, the loss is that of epicritic sensibility alone. What are we to say to a case which shows not only protopathic loss as well as epicritic in the arm and forearm, but on the hand a large area of loss of pain perception without loss of touch perception and its accurate localization. It may be that the extent of this area in the arm and forearm, and the presence of protopathic loss as well as epicritic in these positions, may be due to such incomplete division of the seventh—as well as complete division of fifth and sixth anterior primary cervical divisions—as would cause sensory without motor loss; this, however, leaves unaccounted for the extraordinary nature of the sensory loss in the hand.

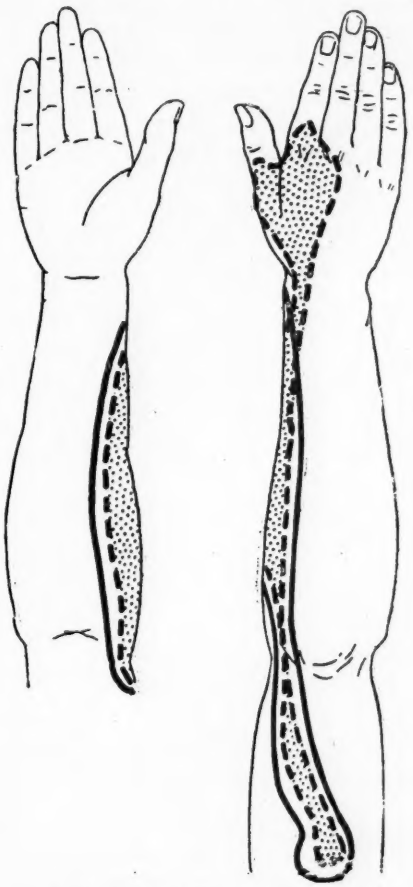

FIG. 339.—*Case* 4.—Showing the 'peripheral nerve' type of sensory loss in the arm and forearm, but an area of dissociation of cutaneous sensibilities in the hand.

The possibilities of diagnosis would seem to be four: (1) A case of pure spinal cord disease or injury; (2) A case of mixed cord and brachial plexus injury; (3) A case of pure brachial plexus injury; (4) A case of injury to the fifth cervical anterior primary division, combined with a lesion of the sensory and motor roots of the sixth cervical segment of the spinal cord.

1. To discuss the first possibility. If this be the correct diagnosis, then we are to imagine a non-progressive lesion—e.g., hæmatomyelia—which involves in one half of the spinal cord the motor cells or their axons of the fifth cervical segment, and also the sensory fibres only of the sixth, or sixth and seventh segments; which at the same time, there being no signs of pasticity anywhere in the body, has not affected the pyramidal tracts of either half of the cord. This seems very unlikely, if not impossible; and even if it were likely or possible, why is not all, and not merely part, of the area of sensory loss of the 'spinal cord' type?

2. The second hypothesis—explaining the 'peripheral' nature of the area of loss on the arm and forearm by assuming a trauma to the peripheral nerve trunks, and the area of dissociated sensibility on the hand by invoking a concomitant slight obstetrical lesion of the fifth cervical segment of the cord—seems to be open to a similar objection to that given in discussing the first purely 'spinal cord' hypothesis.

3. If then—as seems most likely to the writer—this is indeed a case of pure brachial plexus lesion, it seems to suggest that one of the nerve trunks under discussion is an exception to Head and Sherren's law for peripheral nerves—that "in all peripheral nerves the fibres subserving protopathic sensibility have a much wider

overlap than those subserving epicritic sensibility." As we have seen, the fifth cervical anterior primary division is considered to have no area of exclusive sensory supply; moreover, the area of full protopathic supply of this division, as ascertained from the study of residual sensibility and of hyperalgesia in irritative lesions, does not include this area on the back of the hand. Hence it is much more likely, if this third hypothesis be correct, to be either the sixth cervical anterior primary division, or else the whole upper trunk, that—it is suggested—may be forming an exception to the law just given.

4. The fourth hypothesis, however, cannot quite be ruled out of the realm of possibilities, for it is conceivable that a lesion to the fifth anterior primary division, with an intravertebral lesion of the motor and sensory roots of the sixth cervical segment of the cord, might result in some such area of sensory loss.

Lower Arm, or Klumpke, type of Lesion.—

Case 5.—Pte. T. E. was wounded by a large piece of shell in the front of the neck on Oct. 29, 1914; it entered the neck just above the manubrium sterni, and did not emerge. When first seen, Nov. 2, the wound was almost healed.

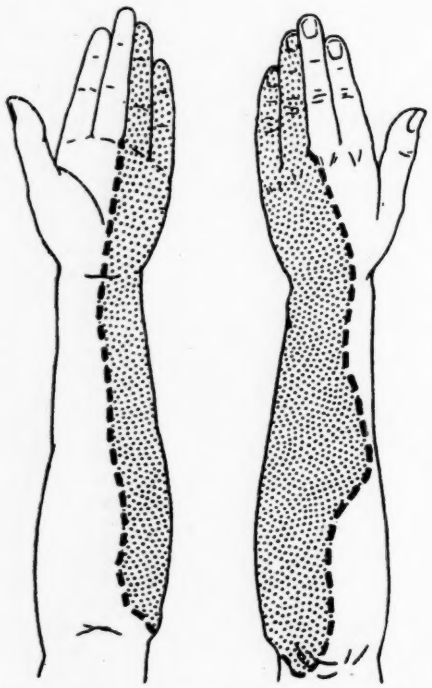

FIG. 340.—*Case* 6.—Showing area of loss of protopathic sensibility.

Nov. 3.—Complaint of pain in left axilla. Friction sounds heard.

Nov. 4.—Left pleural effusion; complaint of 'pins and needles' down the inner side of left forearm and hand. Skiagraph shows a large piece of shell lying behind the inner half of left clavicle. This was removed on Nov. 7.

Nov. 10.—Wound very inflamed; great complaint of shooting pain down inner side of forearm and hand; skin here hyperalgesic.

Nov. 12.—Left pupil small and contracted. The pain has now given place to anæsthesia along the ulnar side of forearm and hand and also in the ring and little fingers. Wasting and weakness of all intrinsic muscles of hand, with development of complete main-en-griffe. Weakness and wasting of flexors of wrist and fingers.

DIAGNOSIS.—The lesion is one of the eighth cervical and first dorsal roots, the pupillo-dilator fibres running in the latter being also affected. These come off in the ramus communicans soon after emergence of the root into the neck.

Case 6.—A. R., age 5. Head presentation, difficult birth, immediately after which paralysis of right arm was noticed. The whole arm at first was paralyzed, but recovery took place in the upper arm.

ON EXAMINATION.—Flail wrist and fingers.

Motor Loss.—No voluntary contraction of the small muscles of the hand, the long flexors of the wrist and fingers, or the long extensors of the fingers.

Electrical Reaction.—None of the above muscles reacted to faradism.

Sensory Loss.—As in *Fig.* 340. Only protopathic loss was tested for.

DIAGNOSIS.—From the motor standpoint, a lesion of D.1 (although there were no orbital signs present), C.8, and part of C.7; this would seem to coincide with the diagnosis from the standpoint of sensory loss.

Lesions of the Cords.—

Case 7.—**Incomplete Lesion of the Outer Cord.**

Pte. A., age 23, complained whilst in hospital of numbness of hand and forearm; no motor affection; sensory loss as in *Fig.* 341. There was nothing to account for this but a history of dislocated shoulder ten years previously.

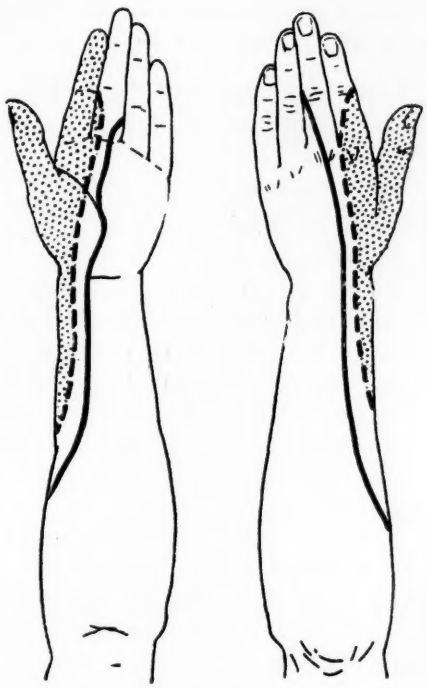

FIG. 341.—*Case* 7.

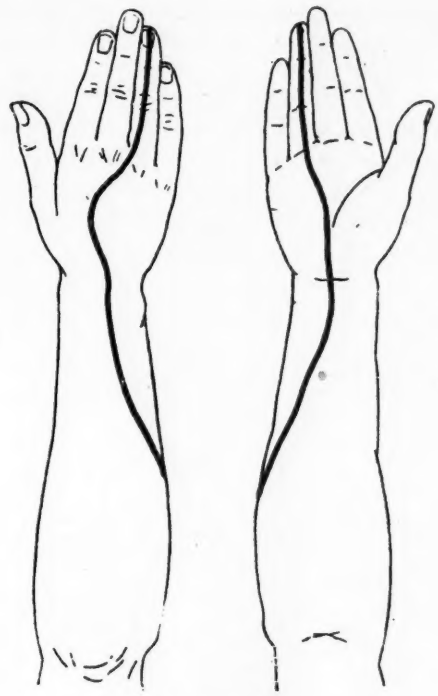

FIG. 342.—*Case* 8.
Loss of epicritic sensibility only.

Case 8.—**Incomplete Lesion of the Inner Cord.**

Pte. T. B., age 38, was wounded by a rifle bullet Feb. 9, 1915, in the right side of the back opposite the upper border of the scapula, of which there was produced a compound comminuted fracture.

Feb. 11.—He complained of numbness in the hand; no loss of motor power; no loss of protopathic sensibility, but of epicritic only, as in *Fig.* 342.

DIAGNOSIS.—Slight lesion of inner cord of brachial plexus.

MUSCULOSPIRAL NERVE AND ITS BRANCHES.

Lesions of the musculospiral nerve and its branches occur altogether eleven times in the series, taking, with the great sciatic nerve, second place in frequency; in five of these cases it was the only nerve to suffer, in the other six there was a concomitant injury to at least one other trunk of the upper limb.

The musculospiral is the peripheral nerve in which the area of sensory loss resulting from its complete division has given rise to most misunderstanding and discussion. This is still a matter of controversy in some cases, and as regards certain points is very variable, a variability depending

apparently on certain complicated anatomic and physiologic arrangements, affecting not only the whole area of sensory loss in degree and extent, but also the relationship to each other of the areas of loss of epicritic and protopathic sensibilities; indeed several cases of the present series prove that to the general law of Head and Sherren that in all peripheral nerves the fibres subserving protopathic sensibility have a much wider overlap than those subserving epicritic sensibility, the musculospiral may be a possible exception. The motor loss is definite, and usually quite obvious.

Lesions in the Lower Third of the Arm, or of the Posterior Interosseous and Radial Nerves in the Upper Two-thirds of the Forearm (i.e., lesions occurring below the point of origin of the external cutaneous branches and motor branches in the arm, and above the point of junction of a branch of the musculocutaneous with the radial nerve in the lower third of the forearm).

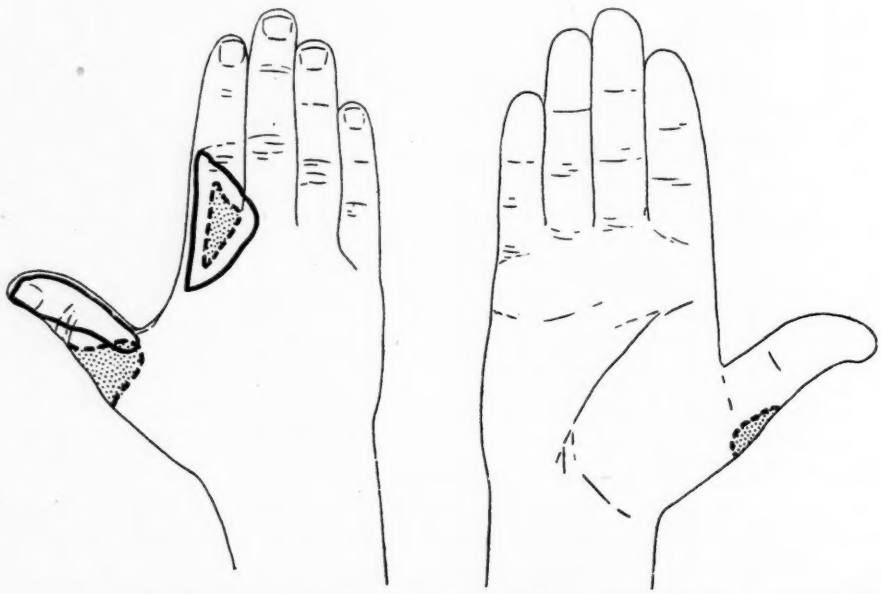

FIG. 343.—*Case* 9.—Complete division of the radial nerve in its upper two-thirds: small areas of epicritic and protopathic loss.

Motor Loss.—Although in these cases with a complete lesion the motor loss is always quite definite, viz., paralysis of the long extensors of the fingers and thumb, with the extensor ossis metacarpi pollicis, the extensor carpi ulnaris, supinator brevis, part of the anconeus, and usually the extensor carpi radialis brevior, yet mistakes may be made in a cursory or rapidly performed examination in connection with the following points:—

a. It is anatomically possible for the extensor carpi radialis brevior to remain unparalyzed, for it may receive its supply direct from the musculospiral in the arm and not from the posterior interosseous (Cunningham), although the writer is unaware that any such case has been observed clinically.

b. In some cases extension of the wrist is possible by the strength of action of the extensor carpi radialis longior alone. This extension, however, is accompanied by abduction of the wrist and hand, i.e., it is extension to the radial side. The extension may cause the actual paralysis to be overlooked, if one is examining for motor loss hurriedly by testing joint movement instead of actual muscle contraction.

c. The patient is unable to extend the metacarpophalangeal joints, and the interphalangeal joint of the thumb, but retains the power of extending the interphalangeal joints of the fingers, a point liable to lead to error if one forgets that this latter movement is performed by the interossei and lumbricals.

Sensory Loss.—Many cases have been recorded of this lesion—complete division of the lower third of the musculospiral or upper two-thirds of the radial nerve—by various writers, without the occurrence of sensory loss at all, notably Sherren's cases, and one by Parry, where two inches of the nerve was destroyed in this position without loss of sensibility on the dorsum of the hand. Indeed, Sherren writes that "complete division of the nerve in the lower third produces no alteration in the sensibility of the dorsum of the hand." The following case, however, and also *Case* 19 (q.v., p. 656) at least suggest, if they do not definitely prove, that this may not be an absolute rule without exception.

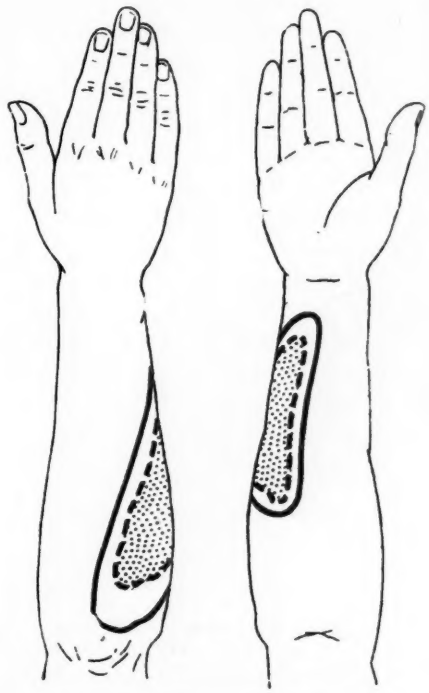

FIG. 344.—*Case* 9.—Complete division of the internal cutaneous nerve at the elbow.

Case 9.—L.-Cpl. H., age 45, was wounded July 14, 1916, in the right elbow region by a rifle bullet, which entered the back of the forearm just external to the neck of the radius, and came out anterior to the internal condyle of the humerus, without producing any bony injury. The patient noticed that weakness of the wrist followed at once on the injury, and persisted.

ON EXAMINATION, Aug. 24.—The wounds had soundly healed.

Position of Limb, etc.—Forearm pronated; drop-wrist; some limitation of full range of pronation.

Sensory Changes.—Loss of epicritic and protopathic sensibilities, as in *Figs.* 343 and 344. No loss of deep sensibility or joint sense. No history of shooting pains or paræsthesiæ.

Motor Loss and Powers.—Voluntary contraction of supinator longus and extensor carpi radialis longior; no voluntary contraction of muscles supplied by the posterior interosseous nerve. The patient could however readily perform extension of the wrist, accompanied by some radial abduction, by the contraction of the extensor carpi radialis longior. There was loss of power to extend the metacarpophalangeal joints and the interphalangeal joint of the thumb.

Electrical Reactions.—No reaction of paralyzed muscles to faradism; with galvanism, K.C.C. greater than A.C.C.

DIAGNOSIS.—A lesion of the internal cutaneous nerve. Also a lesion of either (*a*) the lower third of the musculospiral; (*b*) the bifurcation of the musculospiral; (*c*) both the individual radial and posterior interosseous nerves; or (*d*) any two of these together, or the whole three together, the lesion in any case being clinically, if not pathologically, complete.

OPERATIVE FINDINGS.—The correct diagnosis was found to be (*d*). The lower part of the musculospiral was compressed by dense scar tissue, especially tight and dense around the bifurcation. On tracing down the two branches, the radial was found completely divided, the proximal end, which was bulbous, alone being found, in a mass of scar tissue; the posterior interosseous for about three-quarters of an inch of its course was apparently completely fibrous and adherent to the neck of the radius.

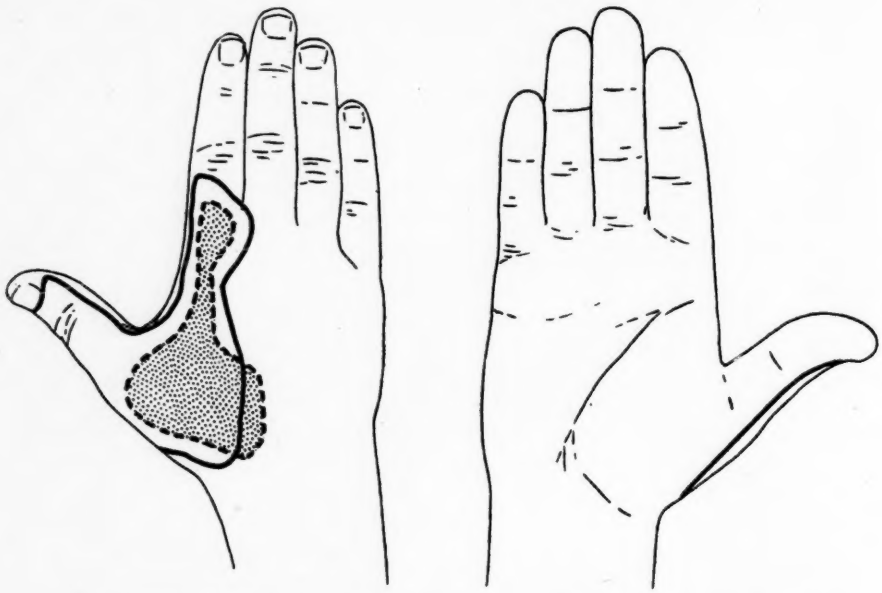

FIG. 345.—*Case* 9.—The areas of loss after operation, showing increase in extent owing to section of the posterior division of the musculocutaneous nerve.

In this case, then, undoubtedly section of the radial nerve in its upper third produced considerable areas of cutaneous sensory loss on the dorsum of the hand. That this was not due to simultaneous subcutaneous division by the bullet of the posterior branch of the musculocutaneous nerve is shown by *Fig.* 345, which represents the post-operative loss, this branch of the musculocutaneous having been cut through at the operation. *Case* 19 (q.v.) is apparently another example of sensory loss with a lesion of the lower third of the musculospiral.

Case 10.—Pte. E. F., age 24, was wounded by a piece of shell in the lower third of the left arm on April 26, 1915. Septic wounds of entrance and exit resulted, without bony lesion.

ON EXAMINATION, May 16.—

Position of Limb.—A combination of drop-wrist and partial main-en-griffe.

Motor Loss and Powers.—Can flex all fingers at the proximal interphalangeal

joints; can flex the three outer fingers, index, middle, and ring, at the distal interphalangeal joint; cannot flex the distal interphalangeal joint of the little finger; can adduct and abduct all the fingers, the interossei and the hypothenar abductor being felt to contract; can adduct the thumb; can extend the interphalangeal joints of the fingers, but cannot extend that of the thumb; cannot extend the metacarpophalangeal joints; cannot extend the wrist, but can contract the triceps and extensor carpi radialis longior and the supinator longus.

Electrical Reactions.—Extensors of the posterior interosseous group except the extensor carpi radialis longior: no reaction to faradism; with galvanism, A.C.C. greater than K.C.C.

Sensory Loss.—As in *Fig.* 346.

Diagnosis.—From these data the diagnosis can readily be deduced. Both from the position of the wounds, and from the fact that the extensor carpi radialis longior and supinator longus contract, whilst the rest of the extensors give the reaction of degeneration, one diagnoses a pathologically complete division of the lower third of the musculospiral nerve. Of course in addition there is an incomplete ulnar paresis.

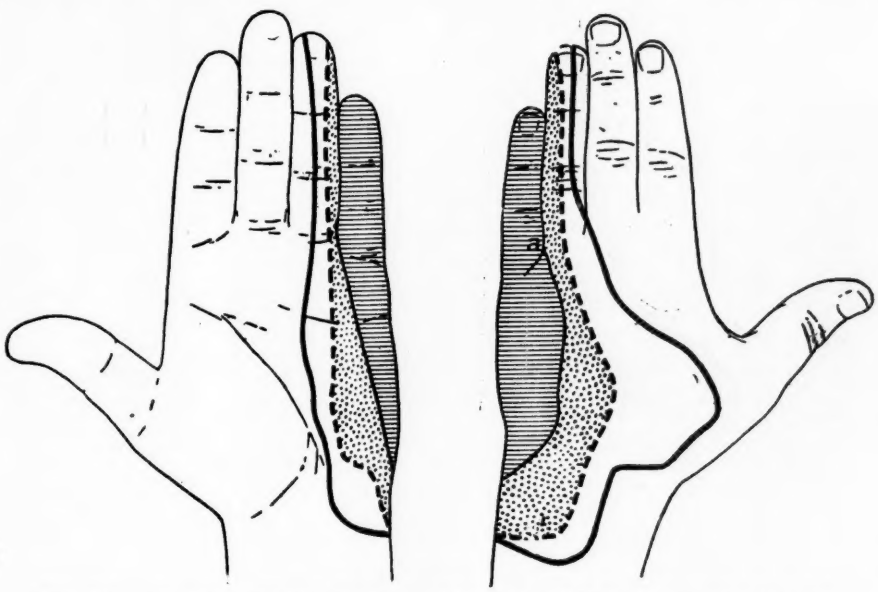

Fig. 346.—*Case* 10.—Showing the areas of loss of sensibilities in musculospiral and ulnar division.

When we come to study the sensory loss in this case (*Fig.* 346), it will be seen that the area of loss of deep sensibility is merely that which occurs in pure ulnar paresis, but that the area of epicritic loss is considerably larger and extends further towards the radial border of the hand than if the ulnar nerve alone had been affected. However, because of the loss of overlap of fibres from the dorsal cutaneous branch of the ulnar nerve, which of course normally occurs, any argument as to the area of sensory loss due to the musculospiral paresis in this case is vitiated, and hence this cannot be regarded as a case throwing any very clear light on this subject.

Case 17, described and discussed later, also falls into this section—division of the musculospiral in its lower third; but since it combines with this a lesion of the musculocutaneous and other nerves, it throws

less light on the chief subject of interest of this section than it does on points subsequently discussed. *Case* 19, however, also given later, is an example of lesion in the lower third with an area of sensory loss in the hand.

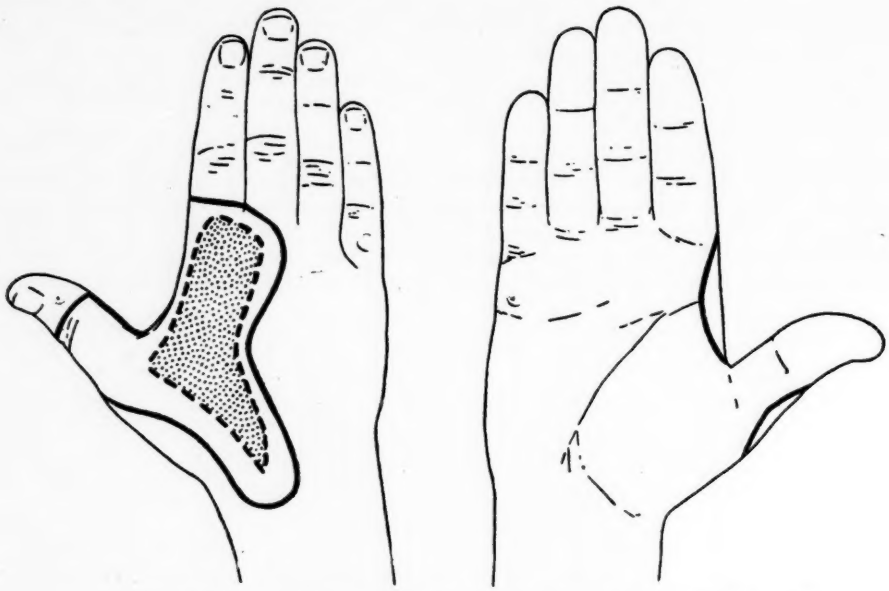

FIG. 347.—*Case* 11.—Areas of epicritic and protopathic loss in full musculospiral division (upper third).

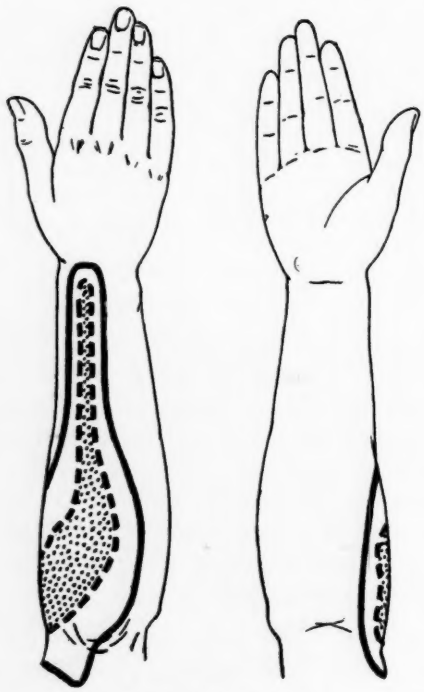

FIG. 348.—*Case* 11.
Areas of sensory loss in the forearm.

Sensory Loss in Lesions above the Lower Third of the Arm (above the point of origin of the external cutaneous branches).—In these cases all authorities are agreed that there occurs some sensory loss, although many hold that this area of loss is limited to the dorsum of the hand, and does not occur on the back of the forearm unless the posterior division of the musculocutaneous is injured in addition to the whole musculospiral. The following cases, however, prove conclusively that this is not so, and that an area of sensory loss may, and often does, occur on the back of the forearm in complete musculospiral division in the absence of musculocutaneous division.

Case 11.—Pte. A. M., age 30, was wounded Sept. 10, 1914, by a rifle bullet in the upper half of the right arm; he noticed paralysis and numbness at once.

On Examination, March 17, 1915.—

Position of Limb.—Complete wrist-drop; forearm pronated; elbow flexed; limitation of full extent of supination; wasting of long extensor muscles on the back of the forearm.

Sensory Loss.—No history of pains or paræsthesiæ, no loss of deep sensibility, other losses as in *Figs.* 347 and 348.

Electrical Reactions.—K.C.C. greater than A.C.C.

Motor Loss and Powers.—Very slight amount of contraction of the triceps; no contraction of any other muscle supplied by the musculospiral.

Diagnosis.—With these facts the diagnosis was complete, viz., division of the musculospiral in the upper third after it had given off at least some of the motor branches to the triceps. Subsequent operation showed this to be correct, the nerve being completely divided below the point of origin of the branch to the inner head of the triceps.

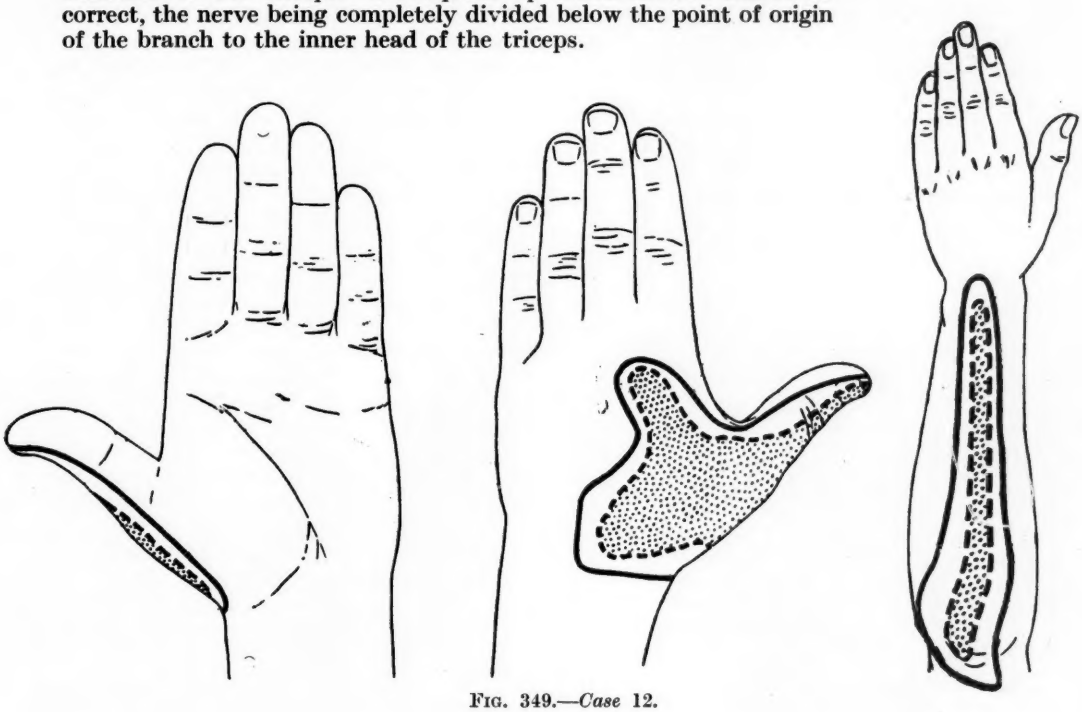

Fig. 349.—*Case* 12.

Here, then, is a case where from the position of the bullet wounds and track it was impossible for the posterior division of the musculocutaneous to be divided, and yet a very considerable area of sensory loss, not only in the hand, but on the back of the forearm, resulted from complete division of the musculospiral in the upper third of its course. The same phenomenon is exhibited in the next case.

Case 12.—Pte. H. C., age 23, was wounded Oct. 27, 1914, by pieces of shrapnel, which produced a compound comminuted fracture of the humeral shaft about its middle.

On Examination, March 8, 1915.—All wounds had healed.

Position of Limb.—Complete wrist-drop, great wasting of extensor muscles and of the triceps.

Sensory Loss.—No history of pains and paræsthesiæ. Numbness noticed at once after injury. Sensory loss as in *Fig.* 349.

Trophic Loss.—On shaving the forearm preparatory to testing the sensation, it was noticed that there was a great accumulation of epidermis, the result of delayed desquamation, over an area corresponding almost exactly with that of the epicritic loss.

Motor Loss and Powers.—Supination performed by the biceps; triceps feebly contracts; cannot extend metacarpophalangeal joints, or wrist-joint, or interphalangeal joint of thumb.

Operation.—In place of the musculospiral nerve there were found mere strands of fibrous tissue, partly embedded in and partly stretched over the callus. Here again there was no question of simultaneous involvement of the musculocutaneous nerve.

Case 13.—Pte. J. O., age 21, was wounded Feb. 14, 1915, in the middle of the left arm by a piece of shrapnel, which passed completely through the arm, leaving septic entrance and exit wounds, and causing a compound fracture of the middle of the shaft of the humerus.

On Examination, March 25.—

Position of Limb.—Wrist-drop; arm pronated.

Sensory Loss.—No loss of deep sensibility; areas of loss of epicritic and protopathic sensibilities as in *Fig.* 350.

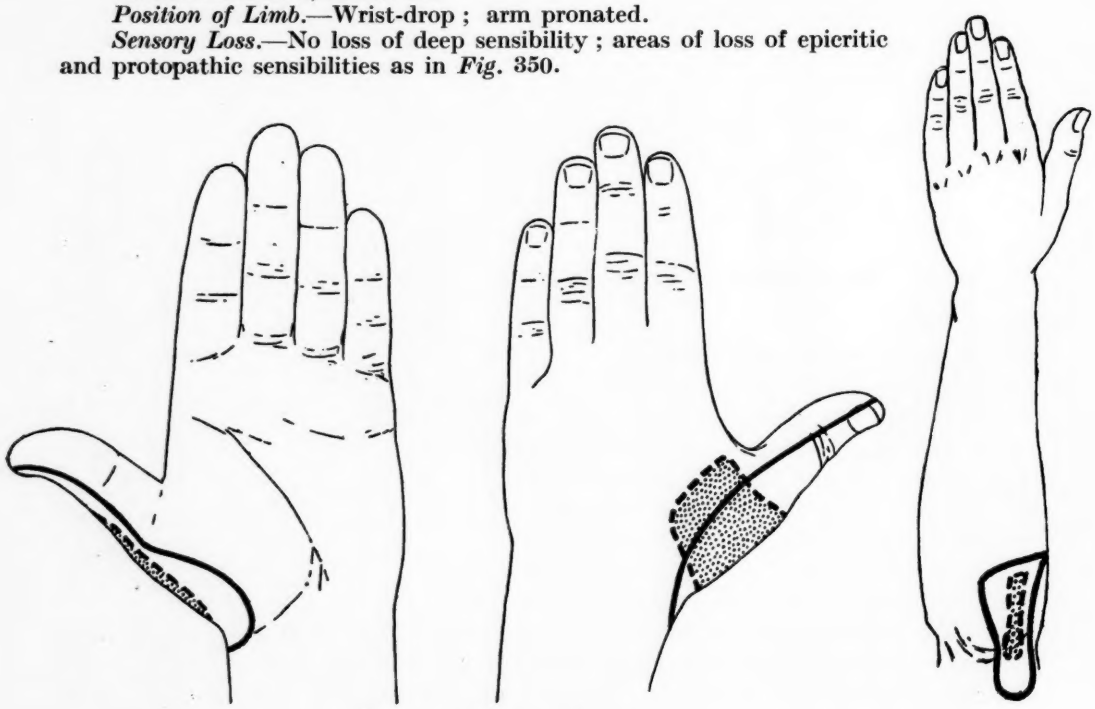

Fig. 350.—*Case* 13.

Motor Powers and Loss.—Cannot extend metacarpophalangeal joints or wrist-joint, but can extend the interphalangeal joints except that of thumb; paralysis of the supinator longus; biceps alone supinates; triceps contracts.

Electrical Reactions.—The paralyzed muscles do not contract on faradic stimulation; on galvanic, A.C.C. greater than K.C.C.

Diagnosis.—This is obviously complete division above the lower third. That this was correct was proved at operation, complete fibrosis of the nerve for over one inch being found in the musculospiral groove. Here, again, is a case of complete musculospiral division, without musculocutaneous division, showing an area, smaller it is true than in *Cases* 11 and 12, of loss of sensibility in the skin of the forearm.

The next case shows the sensory loss that may occur with simultaneous division of the musculospiral and ulnar nerves in the upper half of the arm.

Case 14.—Pte. F. H., age 33, was wounded Nov. 1, 1914, by a rifle bullet, which passed through the inner side of the arm just at the lower margin of the anterior axillary fold, fracturing the surgical neck of the humerus.

On Examination, March 17, 1915.—The wounds had healed and the bone united.

Position of Limb.—Drop-wrist ; forearm pronated ; elbow flexed ; great wasting of one half of the thenar and all the hypothenar muscles and interossei, and of the muscles on the back of the forearm.

Sensory Loss.—Numbness was noticed at once ; loss of deep sensibility as in pure ulnar paresis (see under Ulnar Nerve) ; loss of joint sense in little finger only ; loss of sensibilities as in *Fig.* 351.

Motor Loss and Powers.—Complete paralysis of all muscles supplied by ulnar and musculospiral nerves.

Operation.—This confirmed the diagnosis of division of the ulnar and musculospiral nerves. The lower end of the upper bony fragment, projecting inwards, was densely adherent to the third part of the axillary artery and the musculospiral nerve ; on electrical stimulation of the latter proximal to the lesion, no contraction of muscle occurred. The ulnar nerve was found, with a spindle-shaped enlargement on it, in a mass of scar tissue. This, then, is another example of complete division of the musculospiral nerve, with an intact musculocutaneous, resulting in loss of sensation over a considerable strip of skin on the back of the forearm.

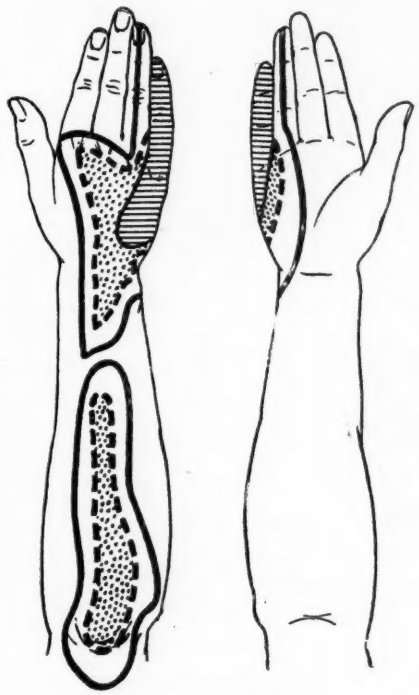

Fig. 351.—*Case* 14.

Case 15.—Sergt. J., age 28, was wounded July 1, 1916, in the right upper arm by a machine-gun bullet, which fractured the humerus at the junction of the upper and middle thirds ; he noticed the drop-wrist at once, and it has persisted.

On Examination, Aug. 30.—

Position of Limb.—Forearm pronated ; wrist-drop.

Sensory Loss.—As in *Fig.* 352. No loss of deep sensibility ; had shooting pains and paræsthesiæ in hand, which commenced one week after injury, and lasted for five weeks ; since then it has completely disappeared.

Motor Powers.—No voluntary contraction of any muscle supplied by the musculospiral except triceps.

Electrical Reactions.—No reaction to faradism. With galvanism : supinator longus and extensor carpi radialis longior, A.C.C. greater than K.C.C. ; other paralyzed muscles, K.C.C. greater than A.C.C.

Trophic Changes.—Marked delayed desquamation over a large part of the area of sensory loss in the hand.

Secretory Functions.—Dryness over area of sensory loss in hand.

Operation, Sept. 7.—There was found incomplete physiological division just as the nerve was emerging from the musculospiral groove. The nerve was flattened and tightly strangled by fibrous tissue ; the lesion had evidently been

caused, not by the projectile, but by fractured bone. The nerve was freed and wrapped in Cargile membrane.

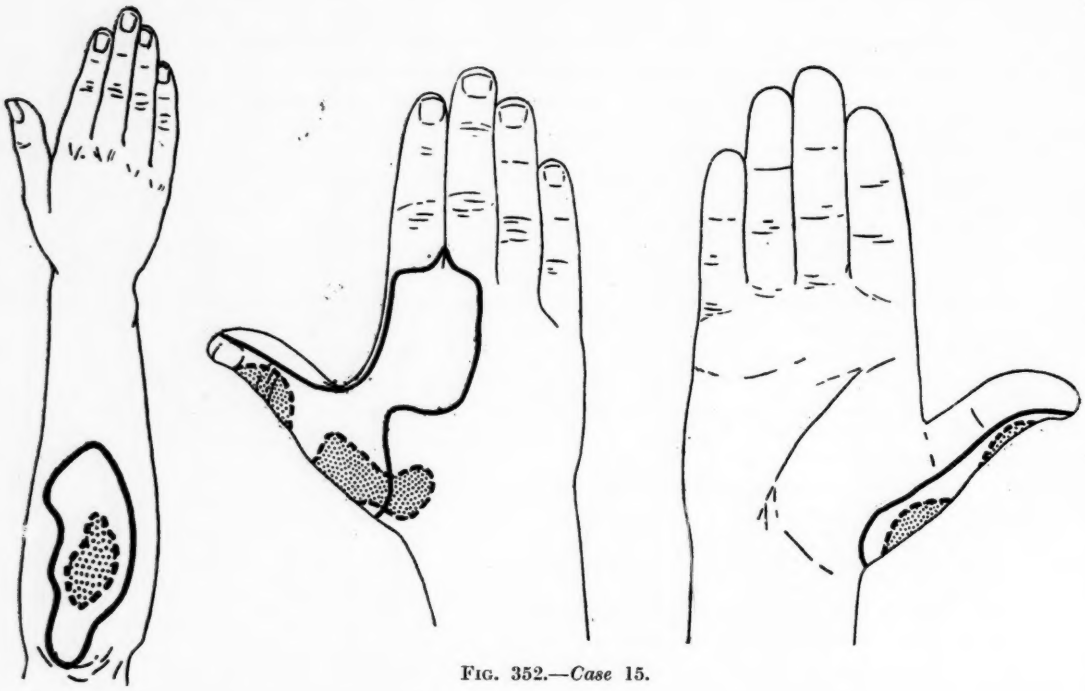

FIG. 352.—*Case* 15.

Here we have another example of an area of sensory loss in the forearm without any lesion of the musculocutaneous nerve.

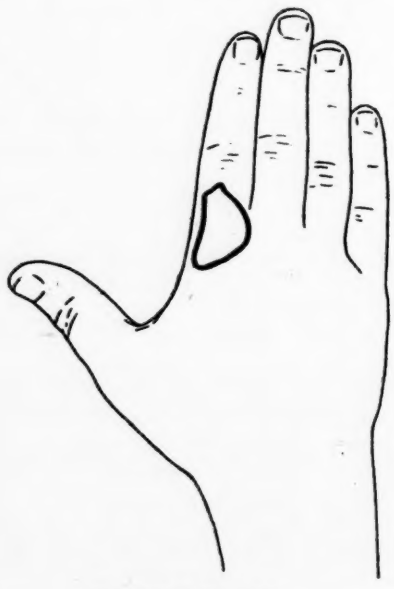

FIG. 353.—*Case* 15.

ON RE-EXAMINATION, Nov. 10.—Very slight return of voluntary motor power; no reaction to strong faradism; sensory loss as in *Fig.* 353.

That those are not wholly in the wrong, however, who hold that such sensory loss does not occur in the forearm is shown by the next case.

Case 16.—Pte. D. was wounded July 19, 1916, in the right upper arm by a rifle bullet which fractured the humerus. He noticed wrist-drop at once, which persisted.

ON EXAMINATION, Aug. 23.—

Position of Limb.—Drop-wrist; forearm pronated; elbow flexed.

Sensation.—Has had no pains or paræsthesiæ, no deep loss, no area of loss in forearm (*Fig.* 354).

Motor Powers.—Complete paralysis of the muscles exclusively supplied by the musculospiral, except the triceps, with the usual disabilities.

Electrical Reactions.—No response to faradism ; with galvanism, K.C.C. greater than A.C.C.

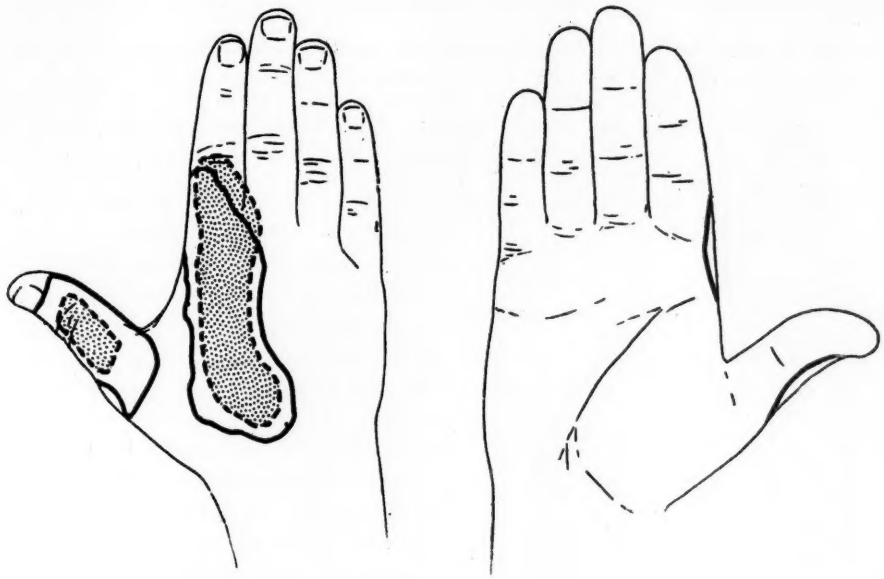

FIG. 354.—*Case* 16.

OPERATION, Aug. 25.—The nerve was found in the triceps muscle, tightly adherent to and stretched over one of the displaced fragments of bone ; it was completely fibrosed for about three-eighths of an inch of its course. This portion was excised and suture performed.

ON RE-EXAMINATION, Sept. 4.—There was no change noted in the sensory loss because of section of the nerve. On Nov. 8, there was no change in the motor or electrical conditions, but a diminution in the sensory loss (see *Fig.* 355).

FIG. 355.—*Case* 16.

Two Instructive and Interesting Cases from the point of view of Sensory Loss.—

Case 17.—**Complete Division of the Internal Cutaneous and Musculocutaneous, with Incomplete Division of the Musculospiral, Ulnar, and Median Nerves, all in the Lower Third of the Arm.**

Pte. F. H., age 23, was wounded on Nov. 1, 1914, in the lower part of the right arm, just above the bend of the elbow, by a large piece of shell which cut away a considerable amount of skin and muscle from the antero-internal aspect of this part of the arm.

On Examination, Feb. 27, 1915.—

Position of Limb.—Elbow flexed; forearm pronated; drop-wrist; little finger abducted; wasting of all intrinsic muscles of the hand; complete main-en-griffe.

Sensation.—Joint sense lost in all fingers and thumb; loss of sensibilities as in *Fig.* 356.

Motor Loss.—Can voluntarily contract all small muscles of the thumb and interossei; can weakly contract the long flexors and extensors of the fingers, wrist, and thumb, and the hypothenar muscles.

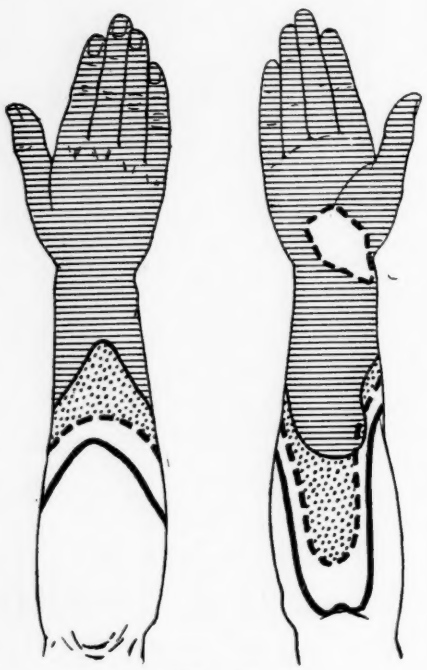

Fig. 356.—*Case* 17.

In this case we have the converse of what obtained in *Cases* 11 to 15 inclusive. In them there was division of the musculospiral nerve, including the fibres which become the external cutaneous branches, and no lesion of the musculocutaneous, resulting in an area of sensory loss extending from the level of the olecranon downwards in varying degree. In *Case* 17, division of the musculospiral, less the external cutaneous branches, but with musculocutaneous division, yields an area of sensory loss extending up the back of the forearm hardly more than half-way, and leaving with sensibility intact a large part of the area affected in the other cases (compare *Figs.* 347–353 with *Fig.* 356).

Case 18.—**Lesion of the Musculospiral above its Lower Third, combined with Incomplete Lesions of the Median and Musculocutaneous Nerves.**

Pte. B. was wounded July 1, 1916, by a piece of shell which passed through the upper end of the left arm just below the level of the inferior border of the anterior axillary wall, and came out behind, causing a compound comminuted fracture of the upper third of the humeral shaft.

On Examination, Aug. 21.—The wounds are not yet healed, and there is a tunnel through the humerus.

Position of Limb.—Pronated forearm; drop-wrist.

Sensation.—As in *Fig.* 357. There was persistent pain down the back of the forearm and in the hand.

Here one sees the sensory loss that occurs in the hand and forearm with simultaneous lesions of the musculospiral and its external cutaneous branch fibres, and the musculocutaneous. For reasons discussed later one might have expected the area of sensory loss in the dorsum of the hand to have been slightly more extensive; but in this case the lesion of the musculocutaneous was incomplete.

Motor Powers.—Voluntary contraction of all muscles supplied by median nerve; also of biceps; no voluntary contraction of the muscles exclusively supplied by the musculospiral, except part of triceps, with the usual disabilities.

Electrical Reactions.—No response to faradism; with galvanism, K.C.C. and A.C.C. about equal, contraction extremely sluggish.

On Re-examination, eight weeks later.—Motor conditions as before. Sensory condition as in *Fig.* 358. The epicritic loss due to the median lesion has disappeared; the epicritic loss on the dorsum of the hand has increased in extent, as has also the area of protopathic loss, both in the hand and in the forearm. The patient has been having less pain.

Obviously the following is now the condition: The median lesion has cleared up; the musculospiral lesion has remained as before; the musculocutaneous lesion has progressed. The area of epicritic loss in the hand now does not fall much more short of the area anatomically supplied by the radial nerve than one would expect to be explicable on the ground of ulnar and median overlap.

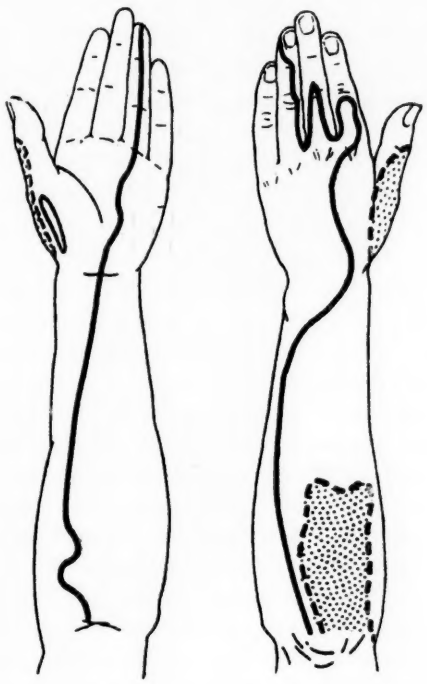

Fig. 357.—*Case* 18.

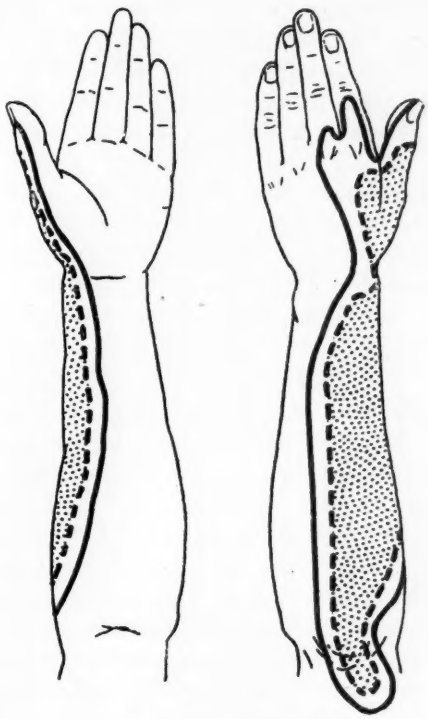

Fig. 358.—*Case* 18.

Résumé of Facts concerning Sensory Loss in Musculospiral Injury exhibited by these Cases.—

1. In no case of pure musculospiral division is there any loss of deep sensibility.

2. Complete uncomplicated division of the musculospiral nerve in its lower third, or of the upper two-thirds of the radial nerve, may result in some cases in no loss of cutaneous sensibility; but *Cases* 9 and 19 seem to prove that this is not so in every case.

3. Complete division in the lower third, with division of the musculocutaneous or its posterior branch, gives an area of sensory loss on the back of the hand which Sherren figures as of great extent. *Case* 17 is an example of this lesion, although the extent of the area is not ascertainable, owing to the presence of the ulnar lesion.

4. Division in the lower third, with division of the ulnar nerve above the point of origin of the dorsal cutaneous branch, produces an area of sensory loss on the 'radial' area of the back of the hand. *Case* 10 is an example of this, in which the area of loss would seem to be purely epicritic in character.

5. Division in the lower third with division of the inferior external cutaneous branch, or uncomplicated division of the nerve above its lower third, produces an area of sensory loss on the dorsum of the hand—e.g., *Cases* 11 to 16 inclusive.

6. Division above the lower third, with either musculocutaneous or ulnar division, gives an area of loss on the back of the hand of maximum size—e.g., *Cases* 17 and 18.

7. Complete uncomplicated division above the lower third may result in an area of sensory loss in the back of the forearm as well as in the hand. Sherren holds that such an area never exists unless there be a concomitant musculocutaneous division. Certainly *Case* 16 supports Sherren's contention; but *Cases* 11 to 15 inclusive show such an area of varying extent without any accompanying musculocutaneous lesion; whilst in *Case* 18, where there is simultaneous division of the musculocutaneous, the area of loss is of considerably greater extent than where the latter nerve is intact.

8. The above-mentioned area on the back of the forearm varies in size from complete absence to a quite considerable strip.

9. The area on the back of the hand varies greatly in size and shape; indeed in some cases it consists of two separate small areas.

10. The area on the dorsum of the hand varies in position, in some cases tending to lie more to the radial, in others more to the ulnar side of the anatomically 'radial nerve' area of supply; in some cases it lies more towards the fingers, in others more towards the wrist.

11. Where division of the musculospiral nerve produces an area of sensory loss on the dorsum of the hand, *Cases* 9, 13, 15, 16, and 19 show that the area of protopathic loss may overlap and extend beyond the area of epicritic loss; whereas it has always been held that in cases of injury to peripheral nerves the former area is included within the latter. Hence these cases constitute contradictions to Head and Sherren's law enunciated above.

It follows from the foregoing that the variations in sensory loss in the case of division of the musculospiral nerve may be classified as follows: (*a*) Variations in extent of the area of sensory loss; (*b*) Variations in position of the area of sensory loss; (*c*) Variations in proportion between epicritic and protopathic loss areas.

a. Variations in Extent of the Area of Sensory Loss.—As regards the area of sensory loss on the back of the forearm, variations in its size are explicable on the ground of the known variations of size of the inferior external cutaneous branch of the musculospiral nerve. Cases of non-existence of this area in musculospiral paresis, e.g., in *Case* 16, are probably instances where this branch supplies a smaller area of skin than usual, and, with that, no exclusive area of skin. In such a case a definite area of loss would occur only if the musculocutaneous or its posterior division were cut also.

In all cases of peripheral nerve division, of course, the area of sensory cutaneous loss—of epicritic loss—never equals in extent the area anatomically

supplied by the affected nerve, this being due to overlapping and supply of the periphery of this anatomical area by nerves supplying the surrounding skin. As will be seen on referring to the various figures, the area of cutaneous sensory loss on the dorsum of the hand is very variable in extent and shape, in some cases being made up of two different separate areas; not only so, but in all these cases it is much smaller than the 'anatomical' area supplied by the radial nerve—very much smaller than one would expect to be explicable on the ground of ulnar or median overlap. Indeed, as we have seen, in many cases of musculospiral division in the lower third of the arm it is entirely absent. That this is not due to ulnar overlapping is made obvious by a glance at *Figs.* 346 and 351, where an ulnar lesion precludes the possibility of ulnar overlap. In *Case* 18, however, where musculospiral and musculocutaneous are both divided, the discrepancy between the actual size of the loss area and that of the anatomically 'radial' area is small enough to be explained by ulnar overlap.

The explanation of these phenomena lies in the fact that this area of skin 'anatomically' associated in the mind with the radial nerve, is really jointly supplied by at least two and sometimes by three different nerves—the radial, the musculocutaneous (posterior division), and sometimes also twigs of the inferior external cutaneous branch of the musculospiral. The variability in the extent of the sensory loss in these cases is evidently due to the fact that in some cases the musculospiral supplies a larger and the musculocutaneous a smaller area, whilst in others the opposite conditions obtain.

b. Variations in Position of the Area of Sensory Loss on the Dorsum of the Hand.—These variations, already noted, are probably due in part to the above-mentioned double, sometimes triple, supply to this particular area; where there is simultaneous median or ulnar paralysis, the loss of overlap doubtless helps to determine the relative position of the sensory loss in this area.

c. Variations in the Proportion between Epicritic and Protopathic Areas of Loss.—Reference to *Figs.* 343, 350, 352, 354, 392 (*Cases* 9, 13, 15, 16, 19), shows the musculospiral nerve to be a possible exception to Head and Sherren's law relating to the overlap of peripheral nerves. The possibility of this was first shown to the writer by *Case* 13, an account of which was published by him in an article, "The Extent and Nature of the Sensory Loss in Musculospiral Paresis," in the September, 1916, number of the *Journal of the Royal Army Medical Corps*; since writing this he has come across the other examples, and apparently the phenomenon is not uncommon in musculospiral lesions, occurring as it does in 50 per cent of the cases in this series.

In this respect Sherren has described an apparently exactly similar phenomenon to that occurring in *Case* 9 (*Fig.* 345), and due to the same cause—simultaneous division of the radial and musculocutaneous nerves—viz., a dissociation of sensibility over a small area on the dorsum of the hand. He has ascribed this to the fibres of the inferior external cutaneous branch of the musculospiral supplying a greater area here with epicritic subserving fibres than that it supplies with protopathic subserving fibres, for he writes that when the whole musculospiral is divided, this dissociation does not occur. *Cases* 9, 13, 15, 16, 19 of this series show that this latter statement is wrong, for in them, with complete division of the musculospiral (radial), this

dissociation has occurred. Doubtless the explanation of the dissociation in these cases is that in them the musculocutaneous fibres supply a larger area with epicritic than with protopathic sensibility, and the radial a larger with protopathic than with epicritic. In *Case* 9—the later state of it—we get an exact replica of Sherren's experimental dissociation, which admits of course of the same explanation.

We therefore conclude that whilst this particular area of the skin of the hand is supplied by at least two, and sometimes by three, different nerves, section of one alone is usually insufficient to cause an area of sensory loss in it. Moreover, we must conclude that the proportion between the number of fibres subserving epicritic sensibility and the number subserving protopathic is not the same in each of the three paths by which such fibres may pass to the brachial plexus from this area of skin.

MEDIAN NERVE.

Cases of division of the median nerve occur seven times only. In four of these it alone suffered; in the other three, other nerve trunks were involved with it. In five cases it was injured in the upper arm; in the remaining two in the forearm. In no case was there a complete anatomical division; indeed, the division was clinically complete in one case only.

Division in the Upper Arm without Lesion of other Nerve.—

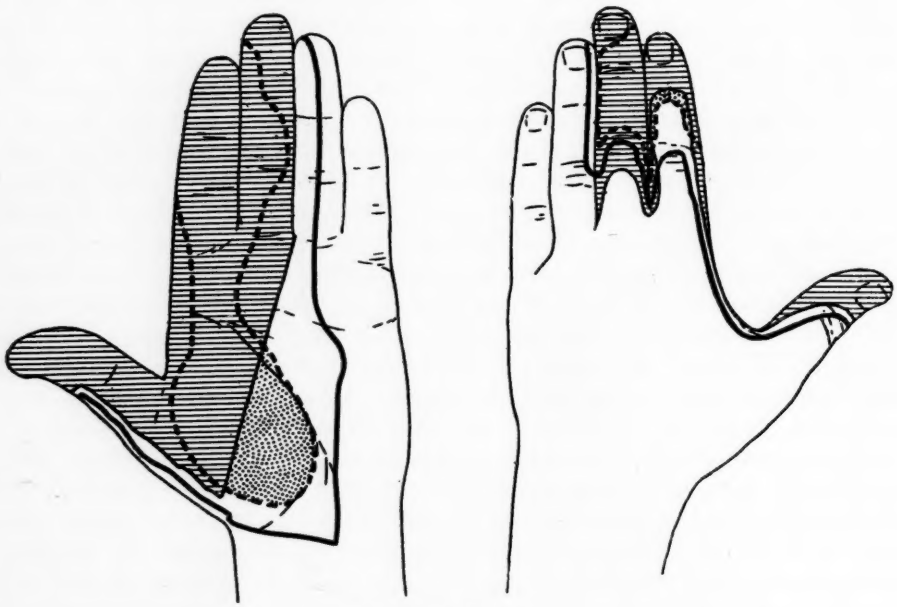

FIG. 359.—*Case* 20.

Case 20.—Sergt. B., age 30, was wounded July 31, 1916, by a rifle bullet in the left upper arm half-way between shoulder and elbow; entrance wound just at inner border of biceps muscle; he noticed numbness in the hand at once.

On Examination, Aug. 28.—

Sensation.—No pain or paræsthesiæ; joint sense lost at interphalangeal joints of thumb, index, and middle fingers; loss of sensibilities as in *Fig.* 359.

Secretory Changes.—No sweating over 'median' area of palm, or on index and middle finger.

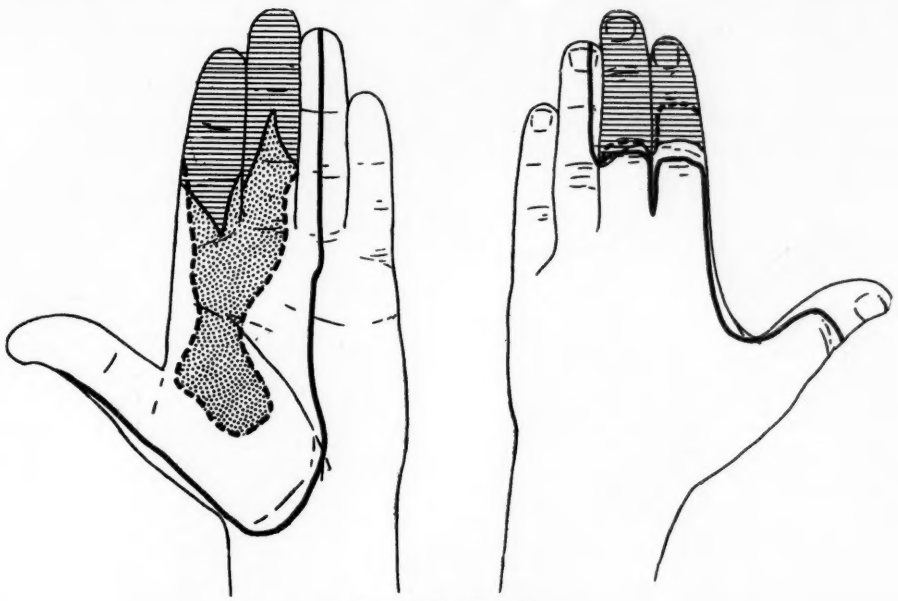

Fig. 360.—*Case* 20.

Trophic Changes.—Delayed desquamation over median area of palmar surface; nails of thumb, index, and middle fingers do not grow so quickly as on other hand.

Motor Loss and Powers.—No voluntary contraction in flexor longus pollicis, flexor carpi radialis longior, pronators, palmaris longus, flexor sublimis digitorum, opponeus, flexor brevis (superficial head), and adductor brevis pollicis; partial loss only (one tendon) in flexor profundus digitorum, for the patient can flex terminal interphalangeal joint of middle finger; cyanosis of index and middle fingers.

Electrical Reactions.—All these paralyzed muscles give no reaction to faradism. To galvanism: forearm muscles, K.C.C. greater than A.C.C.; thenar muscles, A.C.C. greater than K.C.C.

Diagnosis.—The only point that at first sight seems to negative a diagnosis of complete division is the power voluntarily to flex the phalanges of the middle finger. Faradic stimulation of the flexor profundus digitorum also causes flexion at these joints. The reason for this is that in this case the ulnar nerve supplies three, instead of two, slips of this muscle; hence the terminal joint of the middle, little, and ring fingers can be voluntarily flexed. In all these cases, too, the same muscle—not the flexor sublimis—flexes the proximal interphalangeal joint, but in none of them can this latter joint be flexed if the distal joint be voluntarily kept extended. In the index finger, with paralysis of both flexor profundus and flexor sublimis, neither joint can be flexed.

Operation, Sept. 6.—The median nerve was found in scar tissue, completely fibrous for about a quarter of an inch of its length. This part was excised and the nerve sutured.

On Re-examination, Oct. 30.—Motor and electrical conditions as before; sensation as in *Fig.* 360; joint sense partially lost in interphalangeal joint of thumb, absent only in the distal interphalangeal joint of index finger. Recovery of joint sense, deep sensibility, and protopathic sensibility has commenced.

Case 21.—**Incomplete Division in the Upper Arm.**

Pte. G. was wounded by a rifle bullet through the biceps muscle on Sept. 27, 1916, the exit wound being over the line of the brachial vessels.

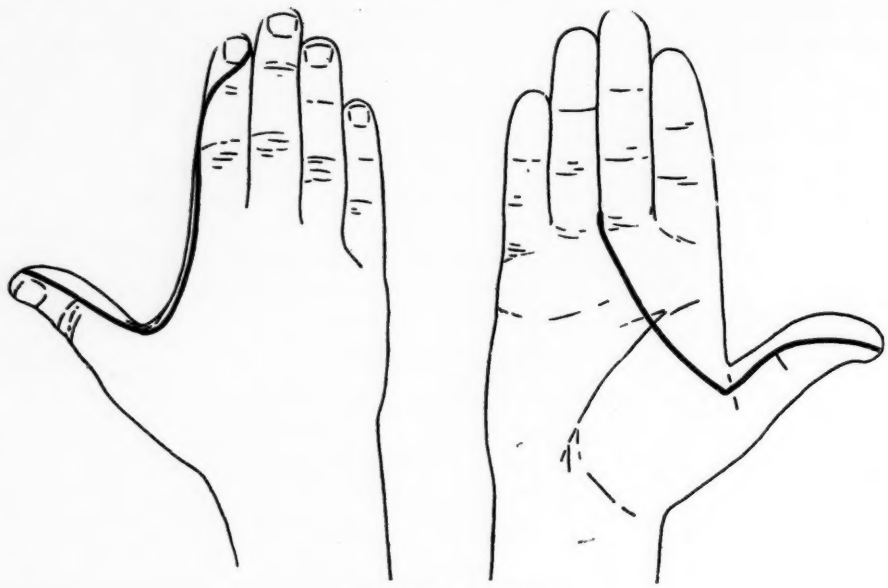

FIG. 361.—*Case* 21.

ON EXAMINATION, Oct. 20.—Great tenderness along the course of median and ulnar nerves below the lesion ; patient has had shooting pains in the hand ever since being wounded. Increase in sweating over median area. Epicritic loss only, as in *Fig.* 361.

Division in Forearm without Lesion of other Nerve.—

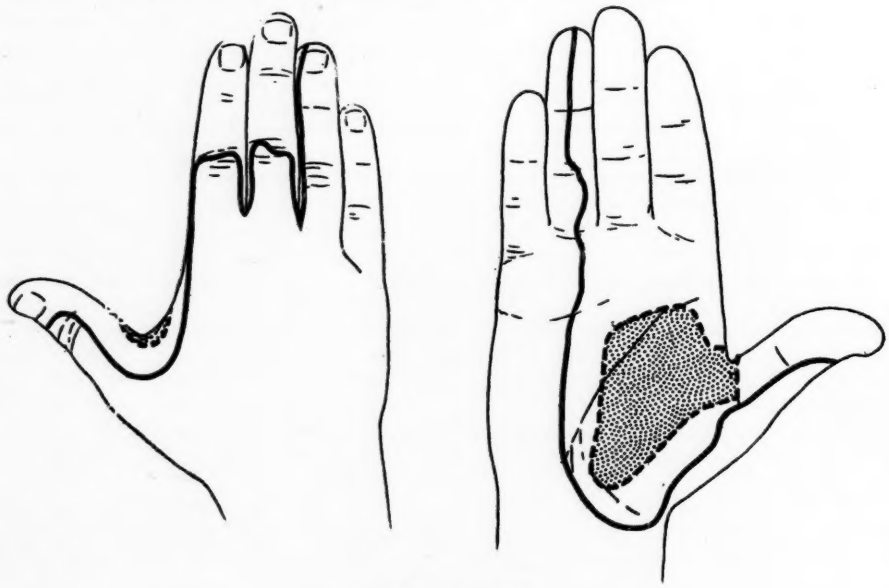

FIG. 362.—*Case* 22

Case 22.—**Incomplete Division in the Forearm.**

Pte. R., age 19, was wounded July 30, 1916, through the middle of the right forearm, half-way between wrist and elbow.

On Examination, Aug. 27.—

Motor Loss.—None ; but there is wasting of the thenar eminence.

Sensation.—No pains, no paræsthesiæ ; no joint sense nor deep sensibility lost ; epicritic and protopathic losses as in *Fig.* 362.

Case 23.—**Incomplete Division in the Forearm.**

Sergt. G., age 27, was blown into the air by a piece of shell July 1, 1916 ; some tiny fragments of metal penetrated his left forearm ; he complained of numbness in hand.

On Examination, Aug. 24.—

Motor Loss.—None ; but there is wasting of the thenar eminence.

Sensation.—Pains in index, middle, and ring fingers for one month ; sensory loss as in *Fig.* 363.

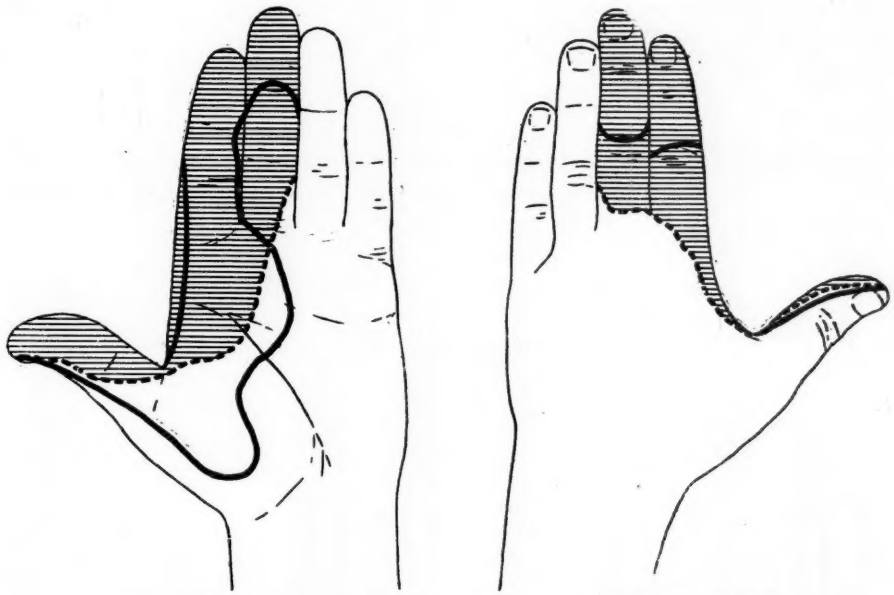

Fig. 363.—*Case* 23.—Areas of loss of deep and epicritic sensibilities.

Diagnosis.—Skiagram shows a tiny piece of metal as small as a pin's head lying in the line of the median nerve.

On Re-examination, Oct. 20.—Patient has had much less pain ; hyperalgesia ; no loss of cotton-wool touch perception ; no loss of joint sense or deep sensibility—i.e., almost complete recovery.

Simultaneous Division of Median, Musculospiral, and Musculocutaneous Nerves in the Upper Arm.—See *Case* 18.

Simultaneous Division of Median, Ulnar, and Internal Cutaneous Nerves in Upper Arm.—See *Case* 34.

Simultaneous Division of Median, Ulnar, Musculospiral, Musculocutaneous, and Internal Cutaneous Nerves.—See *Case* 17.

ULNAR NERVE.

The ulnar is the nerve most frequently injured in this series. A lesion of it occurs in seventeen cases in all; in eleven of these there was pure ulnar paralysis, the ulnar being the only nerve injured; the remaining six were complicated by a lesion of at least one other nerve.

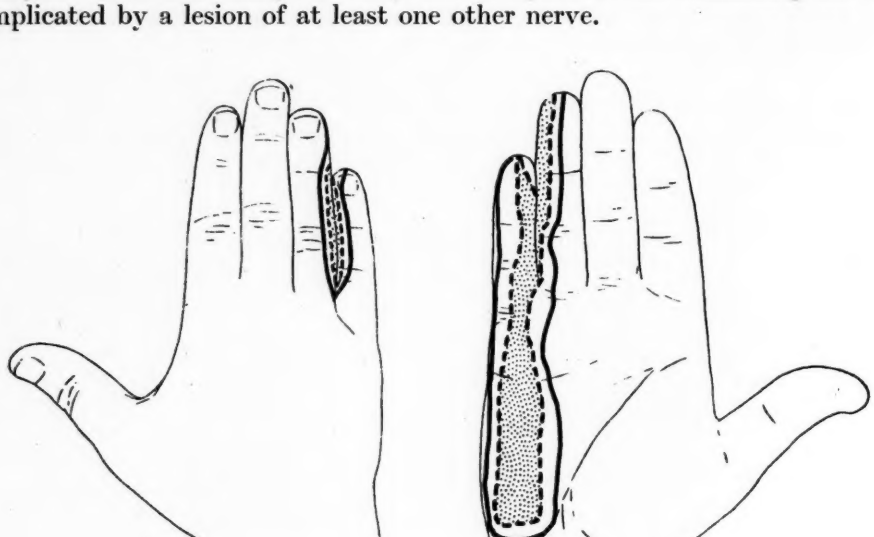

FIG. 364.—*Case* 24.

FIG. 365.—*Case* 25.

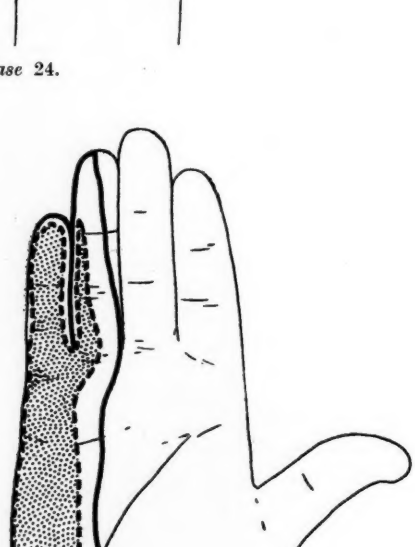

FIG. 366.—*Case* 25.

Ulnar Nerve alone injured, the Lesion being distal to and not involving the Dorsal Cutaneous Branch.—

Case 24.—Rflmn. B, age 20, received a lacerated wound on the front of the right wrist on March 17, 1915.

On Examination, March 28.—There was partial main-en-griffe, and abducted little finger.

Motor Powers and Loss.—No voluntary contraction of hypothenar muscles and of the interossei of the third and fourth spaces.

Electrical Reactions.—The above muscles did not respond to faradism; with galvanism, K.C.C. greater than A.C.C.

Sensation.—As in *Fig.* 364.

Operation, April 1.—Nerve found strangled in scar tissue.

Case 25.—A similar case. The sensory loss is shown in *Fig.* 365. Here also the nerve was found 'compressed from without,' but also nearly completely fibrous; a piece was resected and the nerve sutured. *Fig.* 366 shows the sensory loss three weeks after operation. Before operation, K.C.C. greater than A.C.C.; after operation (resection), A.C.C. greater than K.C.C.

Ulnar Nerve alone injured, the Lesion occurring in the Forearm proximal to the origin of the Dorsal Cutaneous Branch.—

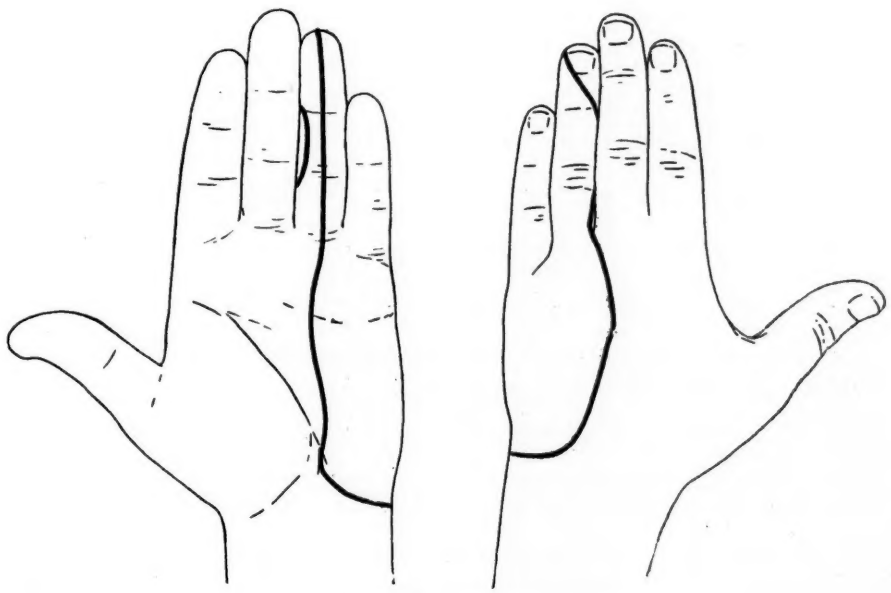

Fig. 367.—*Case* 26.

Case 26.—A lesion of the ulnar nerve in this position—incomplete both from the motor and the sensory standpoints—the result of a gunshot wound. K.C.C. greater than A.C.C. At operation the nerve was found adherent and fibrous in its dorso-external surface. *Fig.* 367 shows the sensory loss, of epicritic sensibility only.

Case 27.—Gunshot wound of the forearm ; no involuntary contraction of ulnar muscles in the hand ; first dorsal interosseous alone reacts to faradism ; sensory loss as in *Fig.* 368 ; K.C.C. greater than A.C.C.

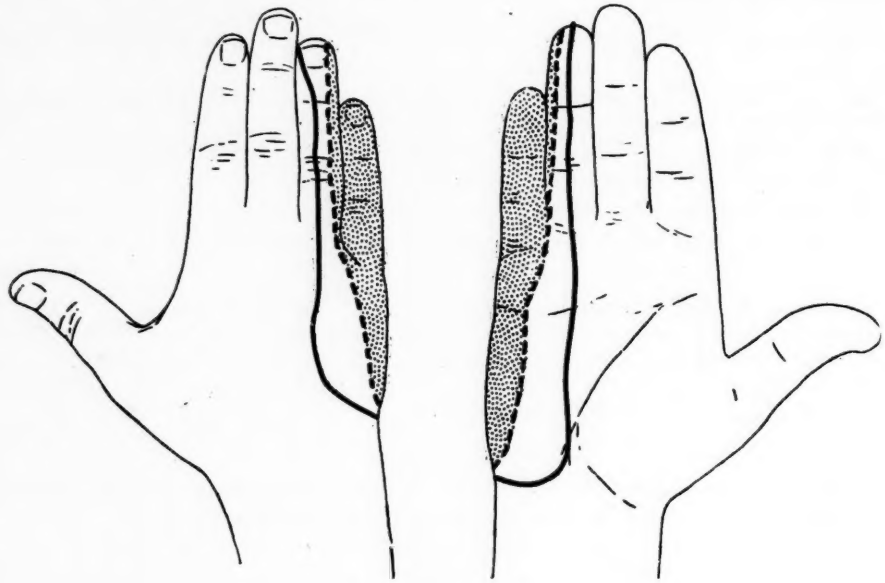

FIG. 368.—*Case* 27.

Case 28.—Rifle-bullet wound half-way between wrist and elbow ; adductores pollicis alone contract of 'ulnar' muscles. To faradism, these and the third dorsal interosseus alone contract, To galvanism: hypothenar muscles and all the interossei, including the third dorsal, A.C.C. greater than K.C.C. Sensory loss completely absent.

DIAGNOSIS.—An incomplete lesion, either (*a*) mending, a previously present sensory loss having recovered—the interval between date of wound and date of examination was, however, only seventeen days ; or (*b*) with that part of the nerve carrying motor fibres alone affected, the lesion being half-way between elbow and wrist. The patient denies ever noticing numbness or shooting pains or paræsthesiæ.

Ulnar Nerve alone injured, the Lesion occurring in the Upper Arm or behind the Internal Humeral Condyle.—

Case 29.—Complete anatomical division half-way between the elbow and shoulder ; full reaction of degeneration in paralyzed muscles.

Sensation.—No pains or paræsthesiæ except on pressure over a palpable spindle, the upper bulbous end ; no loss of joint sense ; other sensory loss as in *Fig.* 369.

Case 30.—Full motor loss ; to faradism no response ; K.C.C. greater than A.C.C. ; pains and paræsthesiæ ; trophic blister on little finger ; loss of joint sense in last joint of little finger only ; areas of sensory losses as in *Fig.* 370. Only the presence of pain and paræsthesiæ negative a diagnosis of a clinically complete lesion.

Case 31.—Case of slight incomplete ulnar division following a fracture of olecranon and lower end of humerus. No motor loss, merely weakness ; hyperalgesia with epicritic loss only, as in *Fig.* 371. On re-examination of case six weeks later, all epicritic loss was recovered.

Case 32.—Sergt. W., age 29, wounded July 7, 1916, in right elbow by shrapnel bullet, which lodged in the lower end of the humerus.

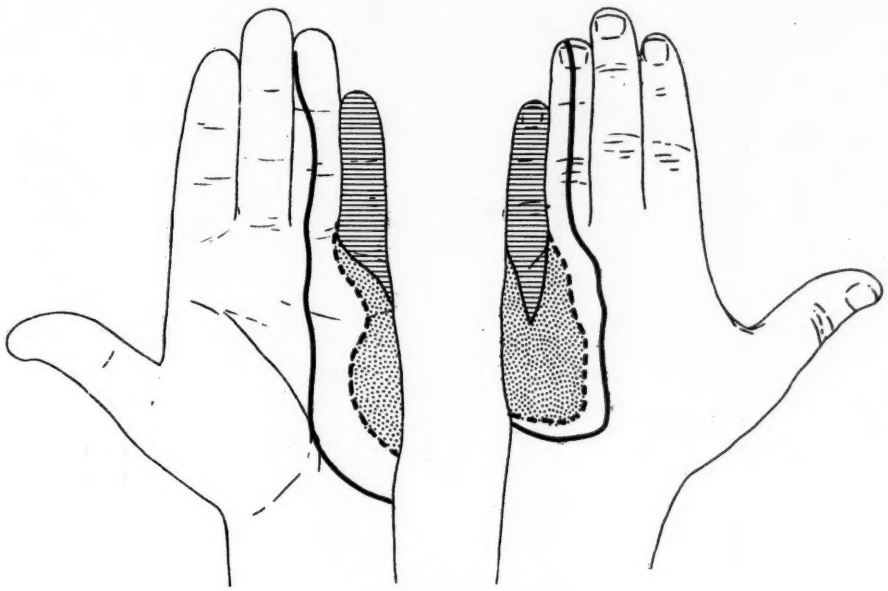

FIG. 369.—*Case* 29.

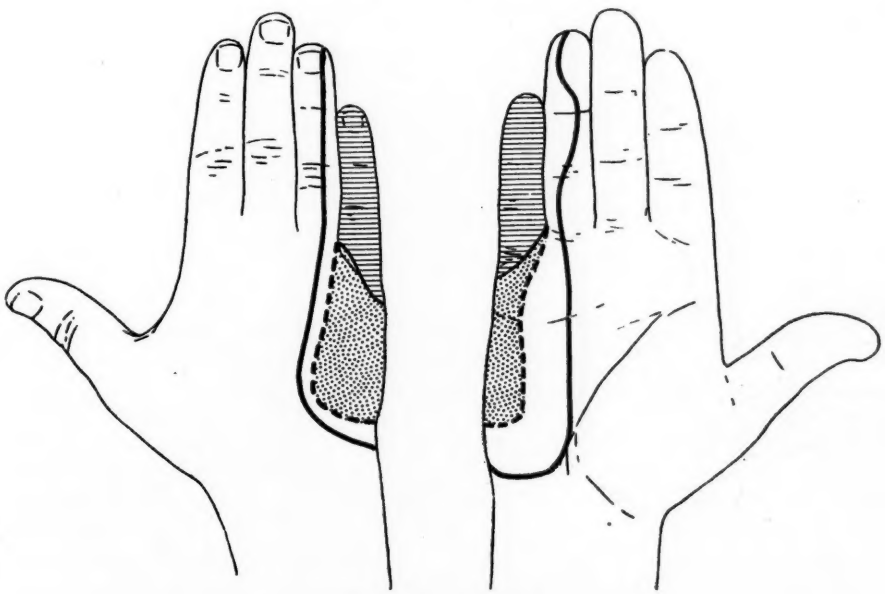

FIG. 370.—*Case* 30.

ON EXAMINATION, Sept. 6.—Wounds healed. Partial main-en-griffe ; a palpable spindle behind internal condyle.

Motor Power and Loss.—No voluntary contraction of any ulnar-supplied muscle except flexor profundus digitorum.

Electrical Reactions.—**The flexor profundus digitorum alone reacts to faradism; to galvanism, the paralyzed muscles show A.C.C. greater than K.C.C.**

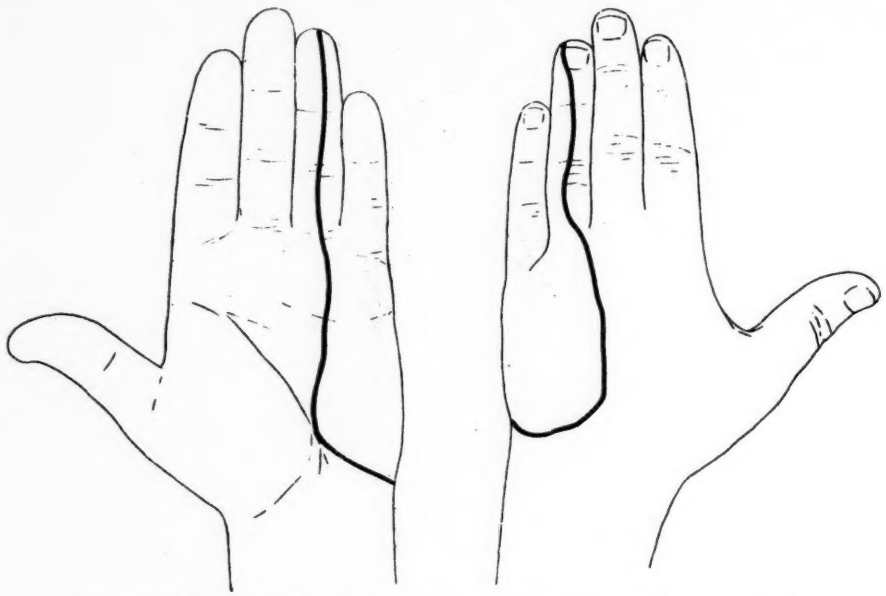

FIG. 371.—*Case* 31.—Slight ulnar lesion. No motor loss. Epicritic loss only.

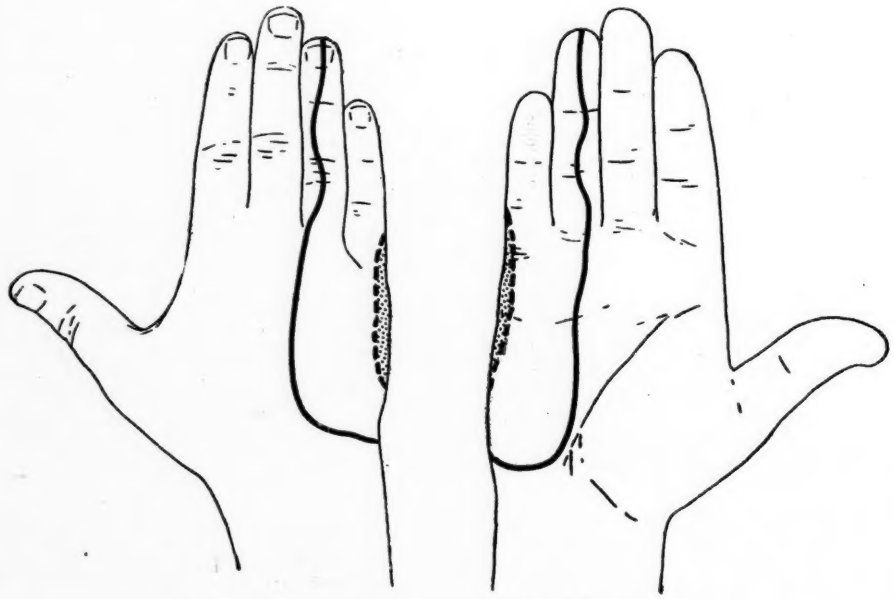

FIG. 372.—*Case* 32.—Incomplete division at elbow.

Sensation.—**No loss of joint sense; no loss of deep sensibility; pains and paræsthesiæ lately only. See *Fig.* 372.**

Secretion.—**Dryness of skin on ulnar side of hand.**

On Re-examination, Oct. 20.—

Motor Powers.—Voluntary contraction of all muscles.

Electrical Reactions.—Flexor carpi ulnaris and flexor profundus digitorum alone react to faradism; 'ulnar' muscles of hand do not respond to faradism. With galvanism: interossei, A.C.C. greater than K.C.C.; hypothenar muscles, K.C.C. greater than A.C.C.

Secretion.—Marked sweating of little and ring fingers.

Sensation.—Hyperalgesia; no loss of cotton-wool touch perception.

Case 33.—Pte. T., age 33, was wounded by a rifle bullet which fractured the lower end of the right humerus, Sept. 17, 1914.

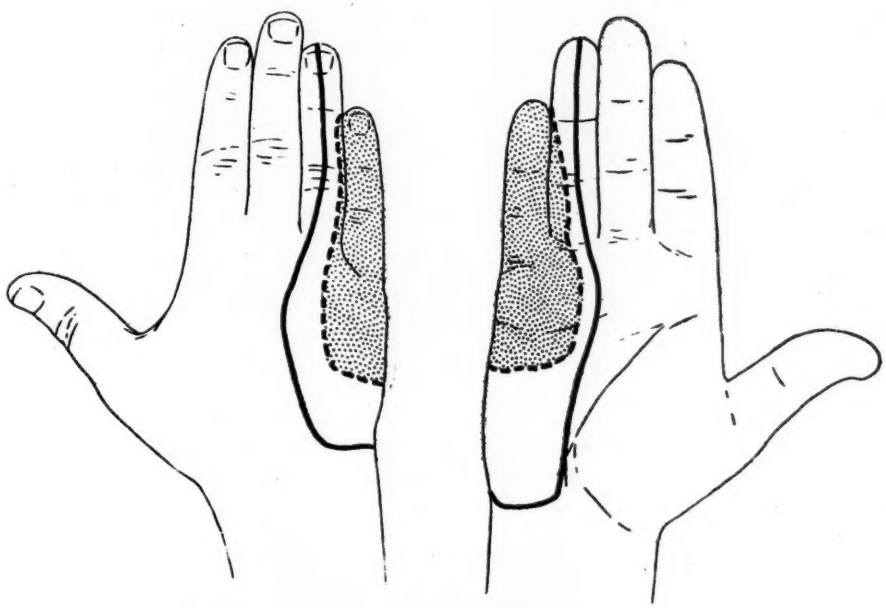

Fig. 373.—*Case* 33.

On Examination, March 5, 1915.—Partial main-en-griffe; abducted little finger; palpable spindle behind internal condyle.

Motor Powers and Loss.—Flexor profundus digitorum and flexor carpi ulnaris alone react voluntarily.

Electrical Reactions.—The paralyzed muscles do not respond to faradism; to galvanism, K.C.C. greater than A.C.C.

Sensation.—No deep loss; joint sense lost in little finger; paræsthesiæ in hand and little finger. See *Fig.* 373.

Diagnosis.—Incomplete division.

Operation.—Excision of spindle, and re-suture of nerve.

On Re-Examination, ten days later.—No loss of deep sensibility; joint sense lost in little finger; epicritic and protopathic loss areas as before.

Simultaneous Division of Ulnar and Musculospiral Nerves.—See *Cases* 10, 14.

Simultaneous Division of Ulnar, Median, and Internal Cutaneous Nerves.—

Case 34.—Patient was wounded by a rifle bullet over line of brachial vessels, half-way between elbow and shoulder, July 1, 1916, a large gaping wound resulting.

On Examination, Sept. 15.—Wound healed ; full main-en-griffe ; great tenderness along course of median nerve.

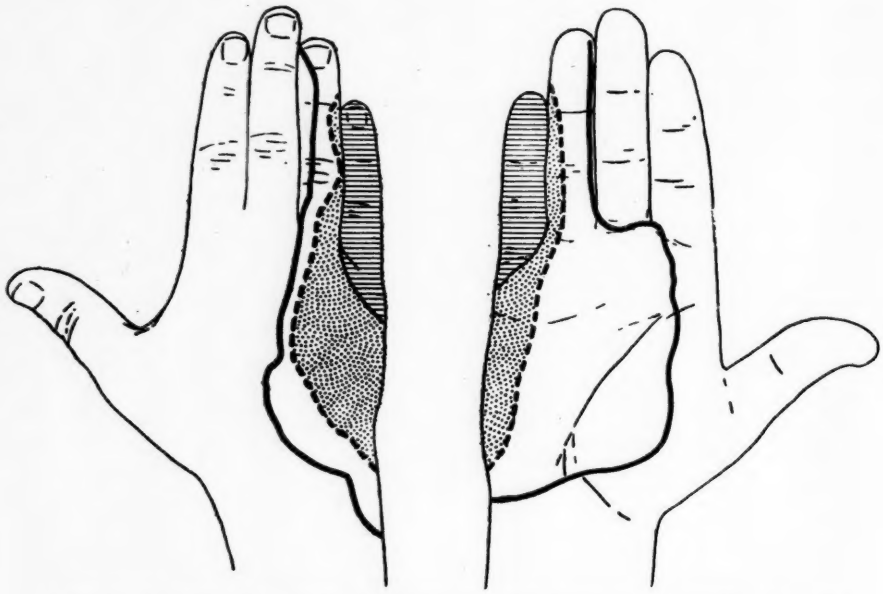

Fig. 374.—*Case* 34.—Complete division of ulnar nerve and incomplete division of median and terminal cutaneous nerves in upper arm.

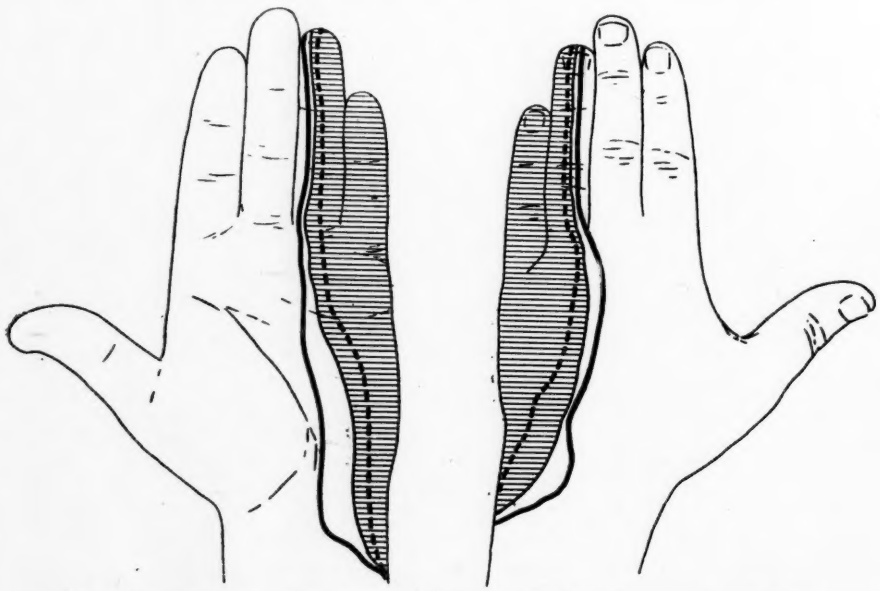

Fig. 375.—*Case* 35.—Sensory loss in ulnar and internal cutaneous division.

Motor Loss.—No voluntary contraction in intrinsic muscles of hand, flexor profundus digitorum, or flexor carpi ulnaris.

Sensation.—Pains and paræsthesiæ in median area of hand; joint sense in last two joints of little finger; loss of sensibilities as in *Fig.* 374.

OPERATION.—Complete anatomical division of ulnar nerve; incomplete 'compression from without' of internal cutaneous and median nerves.

Simultaneous Division of Ulnar and Internal Cutaneous Nerves.—

Case 35.—Simultaneous division just above the wrist of these two nerves, as well as fibrosis of flexor tendons and muscles, and matting together of them.

Sensory Loss.—Joint sense lost in joints of little and ring fingers; for loss of sensibilities, see *Fig.* 375.

Electrical Reactions.—'Ulnar' muscles of hand, A.C.C. greater than K.C.C.

Case 36.—Incomplete division of ulnar at elbow, with complete division of posterior branch of internal cutaneous nerve. See *Fig.* 376 for sensory loss. No joint sense lost, nor deep sensibility.

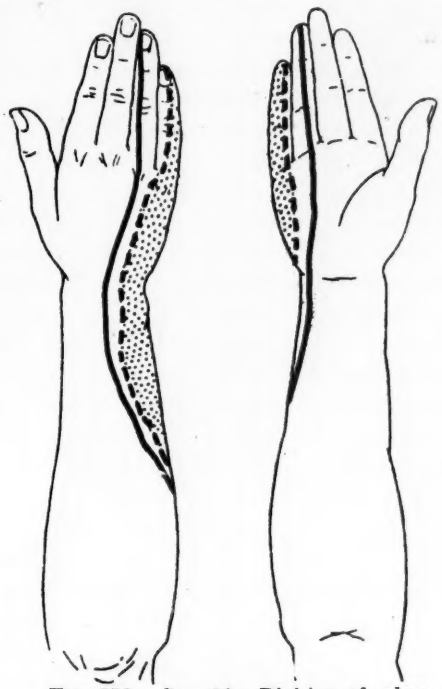

FIG. 376.—*Case* 36.—Division of ulnar (incomplete) and of posterior division of internal cutaneous nerves.

Case 37.—From the nature and extent of the wound, there was complete division

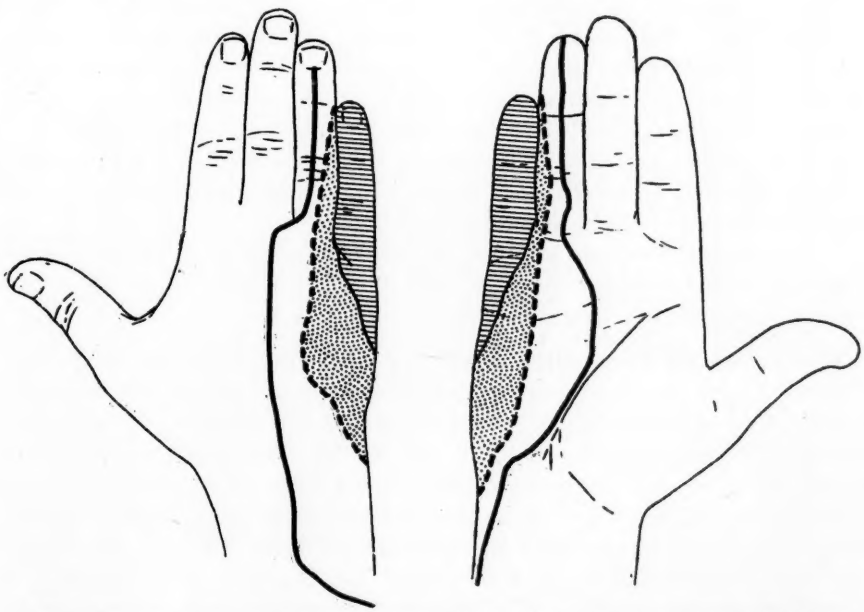

FIG. 377.—*Case* 37.—Complete anatomic division of ulnar and posterior division of internal cutaneous nerves in the upper third of the forearm There was a severe fibrosis of the muscles there also.

of the ulnar nerve in the upper third of the forearm, with complete paralysis of the 'ulnar' muscles of the hand, and full reaction of degeneration; also division of the posterior branch of the internal cutaneous. See *Fig.* 377. The median nerve was split at operation, so that its inner third was able to be anastomosed to the distal end of the ulnar nerve, cut afresh just below the lesion.

Two weeks later there was complete failure of voluntary power in the remaining thenar muscles, and loss of sensation as in *Fig.* 378.

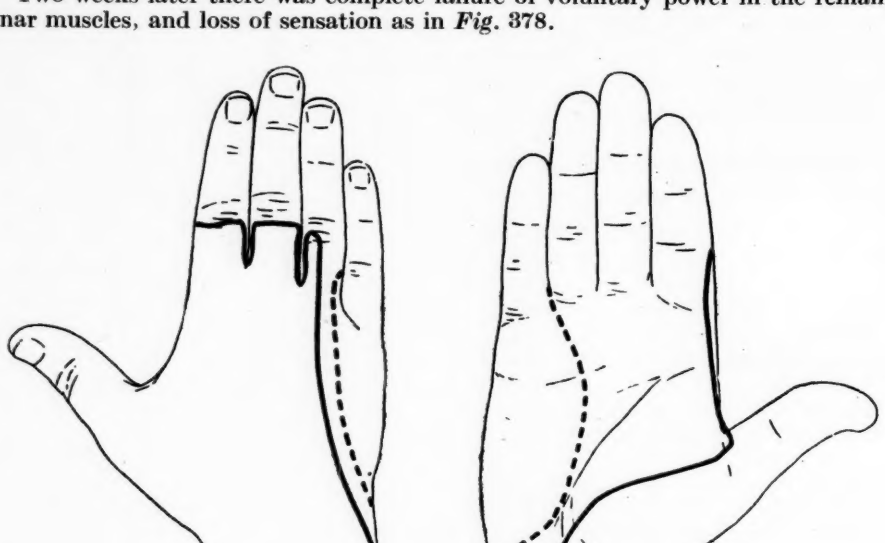

FIG. 378.—*Case* 37.

Noteworthy Points in Lesions of the Ulnar Nerve.—

1. That with a pathologically complete division of the ulnar nerve in the upper arm, with full loss of deep sensibility, there may (see *Cases* 30, 34, 35, 37), or may not (see *Case* 29), be loss of joint sense in the little finger.

2. That unless the internal cutaneous nerve or some of its branches have been also divided, the area of sensory loss in ulnar division never reaches higher than the level of the pisiform bone.

3. That with complete division at the elbow or in the upper arm—i.e., with paralysis of the flexor carpi ulnaris—flexion of the wrist to the ulnar side (flexion plus adduction) is still possible.

The Deformity resulting from Ulnar Division.—In pure ulnar paralysis, the characteristic position of the hand consists of abduction of the little finger and partial main-en-griffe. The abduction of the little and sometimes too of the ring finger would seem to be due to the action of gravity, combined with loss of action of the palmar interossei of the third and fourth spaces. The partial main en-griffe—flexion of the interphalangeal joints of the four fingers, with extension of the metacarpophalangeal joint of the index and middle fingers, but hyperextension of these joints of the ring and little fingers—like all abnormal positions resulting from nerve injuries, is at first capable of being passively though not actively corrected; but in a short space of time

it becomes permanent, becomes indeed not only an abnormal position, but a deformity, contraction of the muscles causing it to become contracture.

This element of deformity is due to the loss of the normal tone and contraction of the interossei and the two ulnar lumbricals. These muscles, the interossei and lumbricals, normally flex the metacarpophalangeal and extend the interphalangeal joints of the fingers, their antagonistic muscles in the former action being the extensores indicis, communis digitorum, and minimi digiti, in the latter the flexores sublimis and profundus digitorum. Hence when in ulnar paralysis the normal contraction and tone of the interossei and two lumbricals are in abeyance, these antagonistic muscles, the balance of power being upset, flex the interphalangeal and extend the metacarpophalangeal joints; and as in the case of the index and middle fingers the lumbricals, supplied by the median nerve, are still in action, the characteristic position does not so fully obtain as in the ring and little fingers, where the action of lumbricals as well as interossei is paralyzed. In simultaneous division of both median and ulnar nerves, as in *Case* 34, the deformity is equally marked in all four fingers, as then all four lumbricals are paralyzed; hence there is complete main-en-griffe. The same condition obtains in lesions of the first dorsal anterior primary division.

CAUDA EQUINA.

***Case* 38.—Shrapnel Wound of Lumbar Spine, with Fracture of the Lamina of the Third Lumbar Verterbra—Right Monoplegia.**

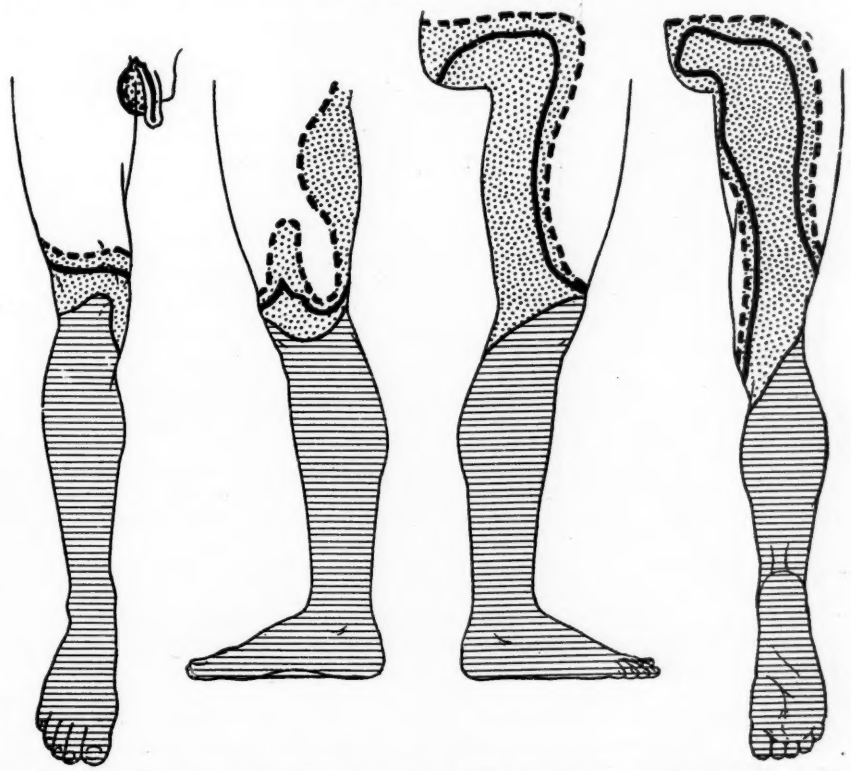

FIG. 379.—*Case* 38.—Lesion of the cauda equina. The sensory loss is of the 'posterior root' type—the protopathic loss area is everywhere of greater extent than the epicritic loss area.

Pte. S., age 22, was wounded July 1, 1916, in the back by a piece of shrapnel. He noticed loss of sensation in the right leg at once, and paralysis. The wound healed up within a fortnight. He had weakness and delay in micturition for three weeks, and marked constipation—no action for twelve days. He states that occasionally for a short time after being wounded he had paræsthesiæ in the leg and foot, and shooting pains in the leg for a few weeks six weeks after the injury.

On Examination, Sept. 10.—A skiagram shows a piece of metal (? in spinal canal) to the right of the middle line, at a depth of 6 cm. from the skin over the spine. Fracture of lamina of third lumbar vertebra. Marked wasting of right leg, thigh, and gluteal muscles, flail ankle, with foot in equinovarus position. No knee-jerk nor ankle-jerk nor plantar reflex; cremasteric and abdominal reflexes present.

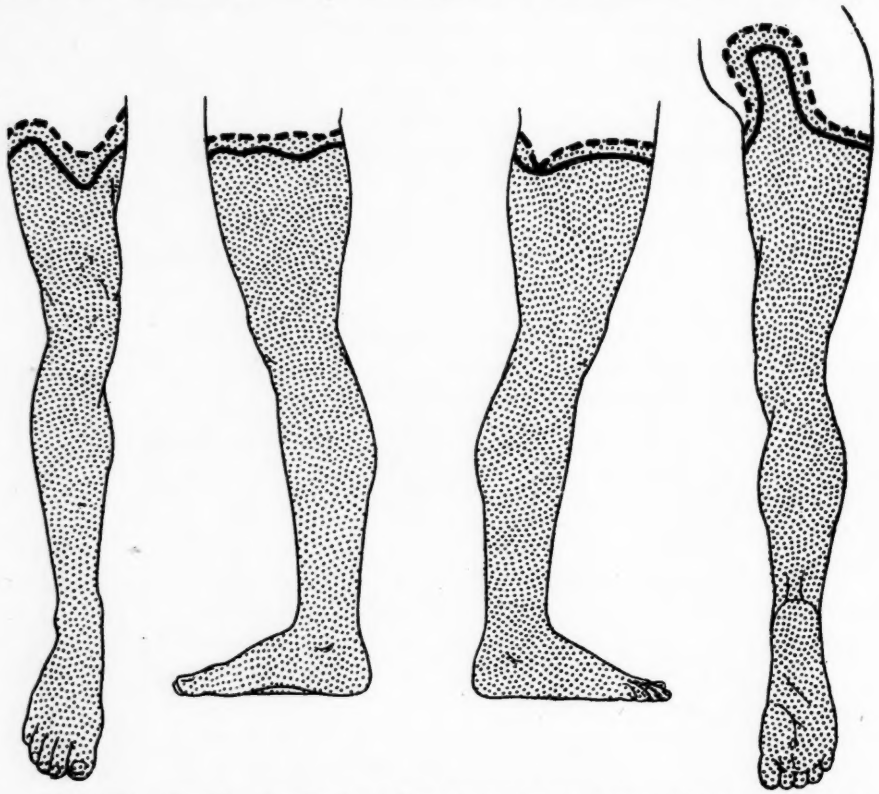

Fig. 380.—*Case* 39.—Sensory loss of the 'posterior root' type affecting the area of distribution of L.4 and 5, and S.1 and 2; loss of deep sensibility not shown.

Motor Power.—Voluntary contraction of adductors, including hamstring part of adductor magnus, abdominal muscles, and quadriceps extensor; no voluntary contraction of hamstrings, gluteal group of muscles, and all muscles below the knee; wasting of glutei on left side.

Electrical Reactions.—No reaction of these paralysed muscles to faradism; with galvanism, K.C.C. greater than A.C.C.

Sensory Loss.—Loss of joint sense in toes, ankle, and knee-joints; the loss of sensibility is of the 'posterior root' type (see *Fig.* 379); great tenderness to pressure along left great sciatic nerve.

Diagnosis.—An incomplete lesion of the right half of the cauda equina, involving chiefly the fifth lumbar and all the sacral roots, motor and sensory.

Operation.—Laminectomy for removal of foreign body—which, however, had penetrated into the body of the vertebra—and raising of the depressed lamina. The

whole right side of the cauda equina was found a mere mass of scar tissue densely adherent to the dura mater. Evidently the projectile had passed through this half of the cauda.

Case 39.—**Incomplete Lesion of Right Half of the Cauda Equina.**

This was a very similar case to the last, with involvement, however, of L.3, 4, and 5, and S.1 and 2, motor and sensory roots.

Pte. T., age 20, was wounded Oct. 23, 1916, by a piece of shell in the middle of the back; wound of entrance at the level of the highest points of the iliac crests. No exit wound. He noticed the paralysis and numbness at once.

On Examination, Nov. 12.—A skiagram shows fracture of the left transverse processes of the third and fourth lumbar vertebræ, with fracture of the spine of the fourth.

Motor Loss.—In right leg alone. No voluntary contraction of quadriceps extensor, adductors, hamstrings, or any muscle below the knee; but he can contract the gluteal muscles.

Sensation.—This is of the 'posterior root' type (see *Fig.* 380); he has some 'deep' loss, but it is difficult to make out its limitations, owing to the tenderness along the course of the great sciatic nerve and its branches; joint sense partially lost in knee, completely in ankle; he has had some paræsthesiæ and shooting pains.

GREAT SCIATIC NERVE AND ITS BRANCHES.

The great sciatic nerve with its more important branches occurs in this series eleven times. The cases may be divided into three classes: Those where the lesion was above or involved the bifurcation into internal and external popliteal nerves—five cases; Those where the lesion lay below the bifurcation, in the course of the internal and external popliteal—two cases; those with lesions of the branches of these two nerves—four cases.

Lesions at or above the Bifurcation.—

Case 40.—Pte. W., age 21, was wounded by a shrapnel bullet in the right thigh, the bullet entering at the outer side of the knee above the head of the fibula, and coming out in the mid-line of the thigh behind. The wounds took three weeks to heal. He noticed the paralysis at once.

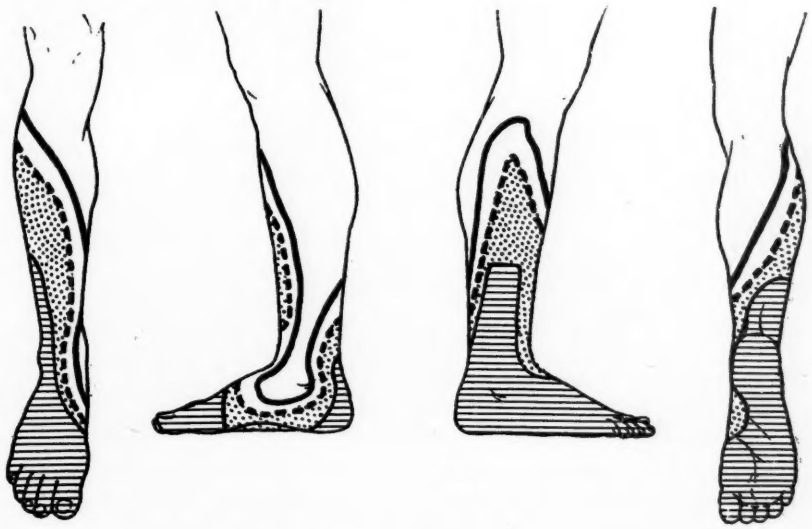

Fig. 381.—*Case* 40.

On Examination, three months later.—

Motor Powers and Loss.—Voluntary contraction of hamstrings; no voluntary contraction of any muscle below the knee-joint.

Electrical Reactions.—No reaction to faradism; to galvanism, K.C.C. greater than A.C.C.

Secretion.—Sweating present below the knee only over the area of supply of the long saphenous nerve.

Sensory Loss.—Joint sense lost in all the toes and in the ankle-joint; he had paræsthesiæ in the foot for several weeks after the injury. See *Fig.* 381.

Diagnosis.—A clinically complete lesion below the origin of nerves to hamstrings.

Operation.—Just at and above the bifurcation there was complete fibrosis of the whole nerve.

The sensory loss in this case is less extensive than in some of the following cases of incomplete division. Probably this is due to variations in the size, and hence in the area of overlap, of the fibres of the small sciatic and long saphenous nerves.

Case 41.—Incomplete lesion just below the buttock.

Pte. McI., age 20, was wounded through the back of both thighs in their upper third, July 1, 1916. He noticed paralysis of the left leg at once.

On Examination, Sept. 27.—

Position of Limb.—Wasting of muscles below knee; talipes equinus.

Motor Powers and Loss.—Paralysis of semimembranosus, semitendinosus, part of adductor magnus, and all muscles below knee-joint.

Electrical Reactions.—No reaction to faradism. With galvanism: posterior muscles of calf, A.C.C. greater than K.C.C.; but peronei, K.C.C. greater than A.C.C.

Sensory Loss.—Tenderness along course of anterior and posterior nerves; he has had constant pain in inner side of foot; partial loss of joint sense in the toes; marked hyperalgesia; epicritic loss as in *Fig.* 382.

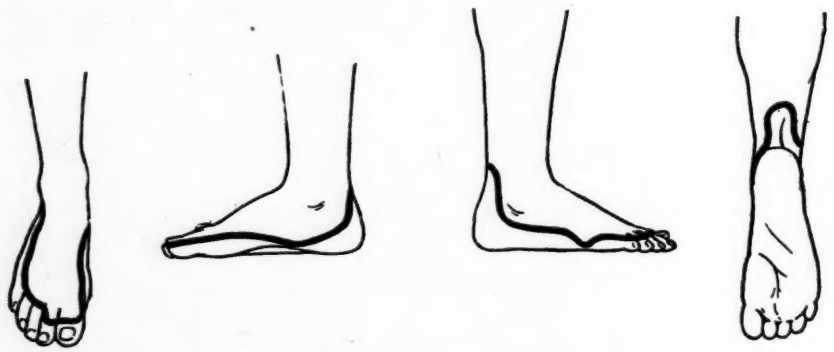

Fig. 382.—*Case* 41.—Showing area of epicritic loss only.

Diagnosis.—The lesion evidently affects chiefly the inner part of the nerve, and of that part, the division of the motor fibres is clinically complete, whilst that of the sensory fibres is very slight. Hence this is an example of a clinically combined complete and incomplete division.

Operation.—This showed compression of the inner part of the nerve by scar tissue.

Case 42.—A case of injury to the great sciatic half-way down the thigh, where, with full motor loss below the knee, there exists a sensory loss as in *Fig.* 383;

but for the presence of paræsthesiæ in the foot, one would diagnose a clinically complete lesion. Comparison of *Fig.* 383 with *Figs.* 381 and 384 shows the areas of sensory loss to be almost identical in extent and nature.

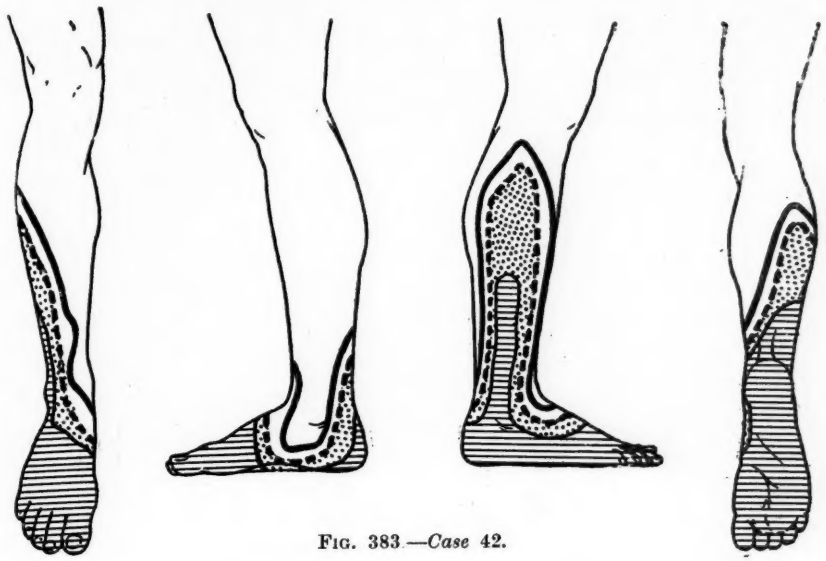

FIG. 383.—*Case* 42.

Case 43.—A clinically complete lesion of the external and an incomplete lesion of the internal popliteal portions at the bifurcation. Paralysis of peronei, extensors

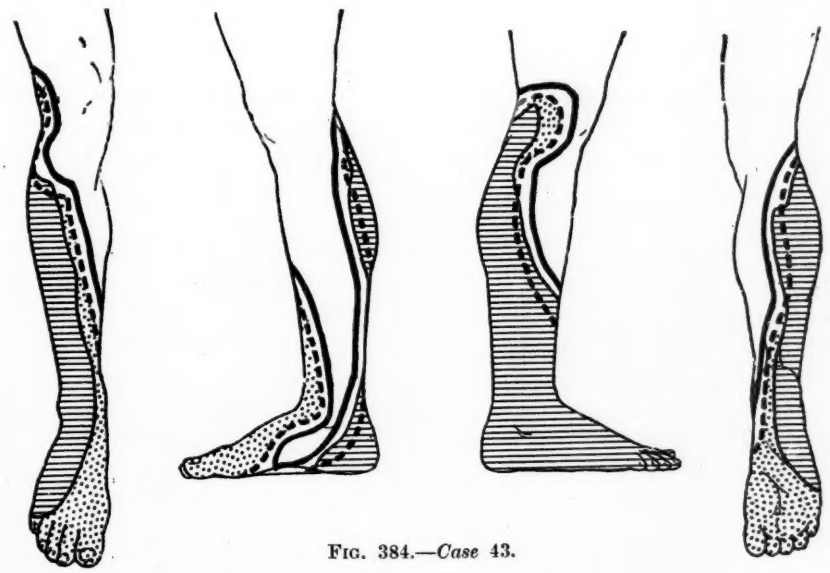

FIG. 384.—*Case* 43.

of toes, and tibialis anticus, with voluntary contraction of posterior muscles of the calf and muscles of the sole. In the paralyzed muscles K.C.C. and A.C.C. are practically equal, with no reaction to faradism. Sensory loss as in *Fig.* 384; no

loss of joint sense ; presence of paræsthesiæ and shooting pains. At operation, the external popliteal was completely fibrous at the bifurcation, whilst the internal popliteal was compressed by scar tissue.

Case 44.—Incomplete division above the bifurcation. Paralysis of peronei, tibialis anticus, and extensors of toes only. No reaction of these to faradism; K.C.C. greater than A.C.C. A great deal of shooting pain, which has made patient emotional and hysterical ; no loss of joint sense or deep sensibility ; sensory loss as in *Fig.* 385 ; great tenderness of the anterior and posterior tibial nerves. The lesion even of the external popliteal portion is incomplete.

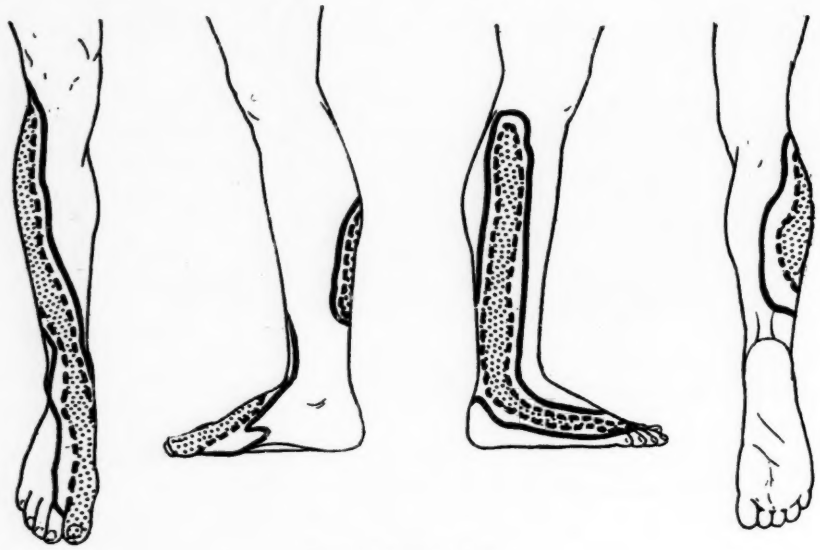

Fig. 385.—*Case* 44.

Lesions in the Course of the Internal and External Popliteal Nerves.—In the five cases just detailed, the lesion occurred in the course of the nerve above the origin of motor branches to muscles below the knee and of sensory branches supplying the tissues below the knee; in all of them the only other sources of sensory fibres supplying these tissues were the small sciatic and long saphenous nerves. In the class of case now to be described, the lesion lies below the bifurcation, but above the point of division of the external popliteal into anterior tibial and musculocutaneous, and above the point where the internal popliteal becomes the posterior tibial. There are no motor branches given off in this part of these nerves ; but the following important sensory branches arise: the nervus communicans tibialis and the nervus communicans fibularis, which unite to form the short saphenous nerve ; and the external cutaneous branches of the external popliteal. Cases of injury of the nerves above the origin of these branches will be indistinguishable from cases of similar severity in the class just described (see *Case* 45); but cases of injury below them will display very much smaller areas of sensory loss ; also in such cases most commonly only one of the two nerves will suffer.

Case 45.—Incomplete division of both nerves below the bifurcation, but above the origin of sensory branches. Paralysis of peronei alone, which alone also fail to

respond to faradism ; K.C.C. greater than A.C.C. ; position of equinovarus. Tenderness along posterior tibial nerve ; no loss of joint sense or of deep sensibility ; losses of sensibility as in *Fig.* 386.

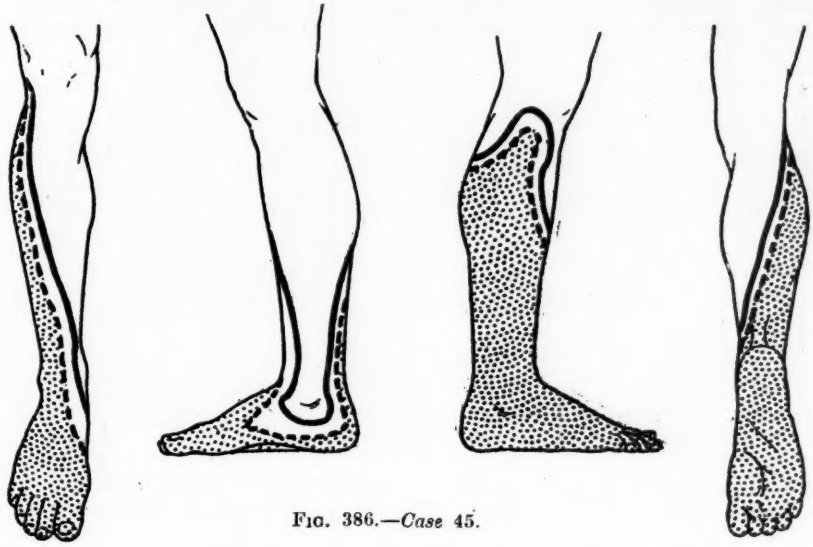

FIG. 386.—*Case* 45.

In this case the areas of epicritic and protopathic loss are equal to those of practically full loss of both parts of the nerve ; the motor loss, however, is slight.

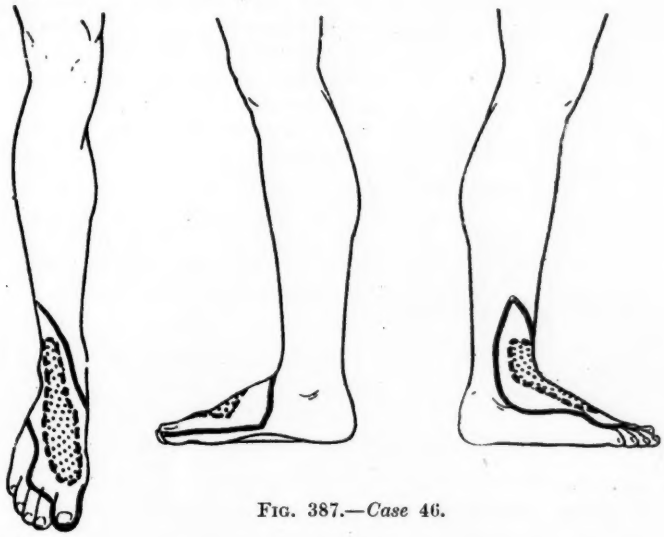

FIG. 387.—*Case* 46.

Case 46.—Lesion of the external popliteal just before its bifurcation.

Patient was wounded July 14, 1916, at outer side of head and neck of fibula, with fracture of the upper end of this bone. Paralysis was noticed at once. On Oct. 26 there was paralysis of peronei and tibialis anticus and extensors of toes. These do not react to faradism ; K.C.C. greater than A.C.C. No loss of deep sensibility ; sensory loss as in *Fig.* 387.

Lesions of the More Important Branches of the Two Nerves.—

Case 47.—**Division of the Anterior Tibial Nerve.**

Patient was wounded by a piece of shell which fractured the upper ends of the fibula and tibia; foot-drop noticed at once. No voluntary contraction of tibialis

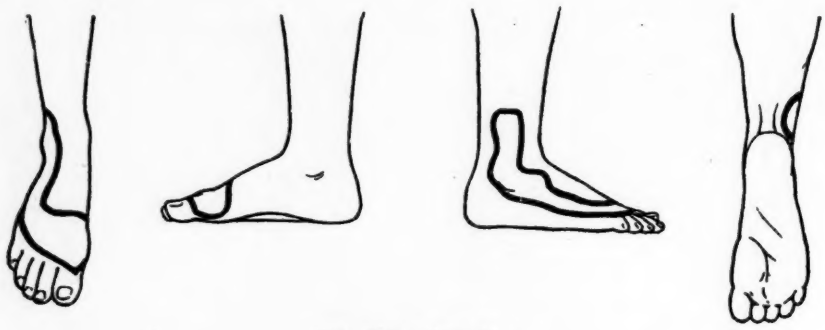

FIG. 388.—*Case* 48.

anticus and extensors of toes; these do not react to faradism, and with galvanism A.C.C. is greater than K.C.C. No sensory loss at all, but occasional paræsthesiæ in the toes.

Case 48.—**Lesion of the Anterior Tibial and Musculocutaneous Nerves.**

Entrance and exit wounds of a bullet at the junction of upper and middle thirds of left leg, with compound fracture of fibula. Paralysis of extensor proprius hallucis only. Has had shooting pains from wounds to toes; paræsthesiæ on pressure over the wounds, or on tapping of the leg, or on coughing; tenderness of anterior tibial nerve distal to the wounds; no loss of protopathic sensibility; epicritic as in *Fig.* 388.

DIAGNOSIS.—Incomplete division of anterior tibial nerve below the branch to extensor longus digitorum, but above that to extensor proprius hallucis, and incomplete division of musculocutaneous below point of origin to peroneus longus and brevis.

FIG. 389.—*Case* 49.

Case 49.—**Lesion of the Short Saphenous Nerve.**

The injury was caused by a shell wound in the middle of the calf. Sensory loss as in *Fig.* 389.

Case 50.—**Lesion of the Musculocutaneous and Short Saphenous Nerves.**

Pte. C., age 25, was wounded by a rifle bullet Sept. 28, 1916, in the outer side of the middle of the right calf; there were in-and-out clean wounds through the peronei and calf muscles. He noticed numbness in the foot at once.

ON EXAMINATION, Oct. 12.—Sensory loss as in *Fig.* 390; shooting pains in foot; on pressure over anterior wound paræsthesiæ occur in the foot. The significance of this area of loss of 'pin prick' sensibility will be discussed later.

On Re-examination.—On Oct. 15 there was no change; but on Oct. 26 the sensory loss had returned to the normal type, as shown in *Fig.* 391,

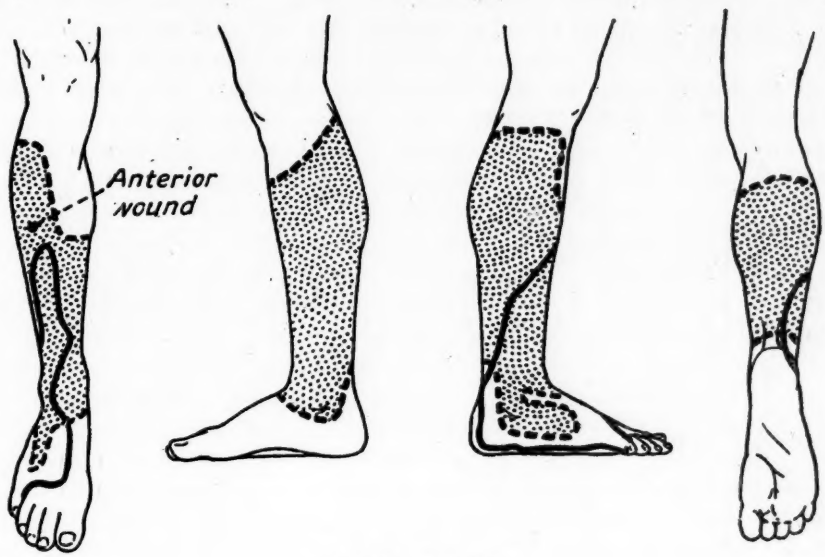

Fig. 390.—*Case* 50.

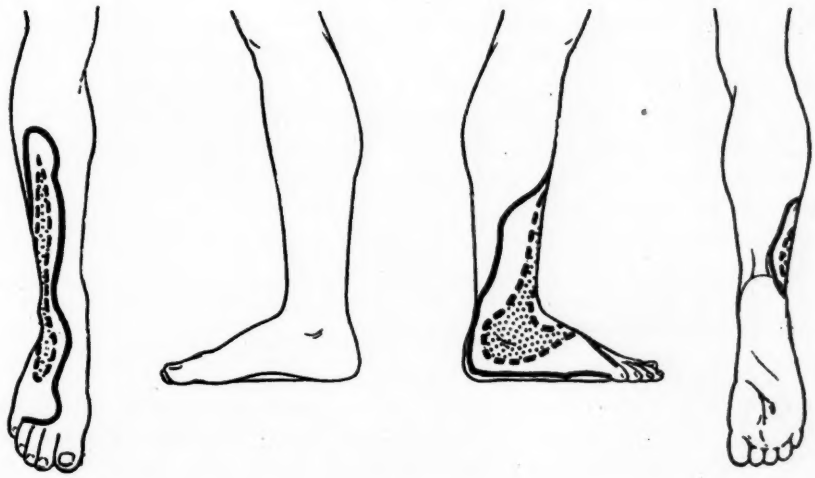

Fig. 391.—*Case* 50.

THE CONCUSSION OF SUBCUTANEOUS NERVES IN GUNSHOT WOUNDS.

It is common on questioning wounded soldiers to elicit the remark that that portion of the limb distal to the wound felt and remained 'numb' for some days subsequent to the infliction of the injury. Whatever may be the literal accuracy of such statements, *Case* 19, a gunshot wound of the musculospiral nerve, and *Case* 54, a wound of the musculocutaneous nerve of the leg,

seem to indicate that some condition of interference with subcutaneous nervous conduction, or some subcutaneous nervous excitability, may be produced, the result possibly of some process of concussion of subcutaneous nerves within a certain radius of the skin wounds.

Case 19.—Pte. S., age 23, was wounded Sept. 15, 1916, by a piece of shell in the lower half of the left upper arm.

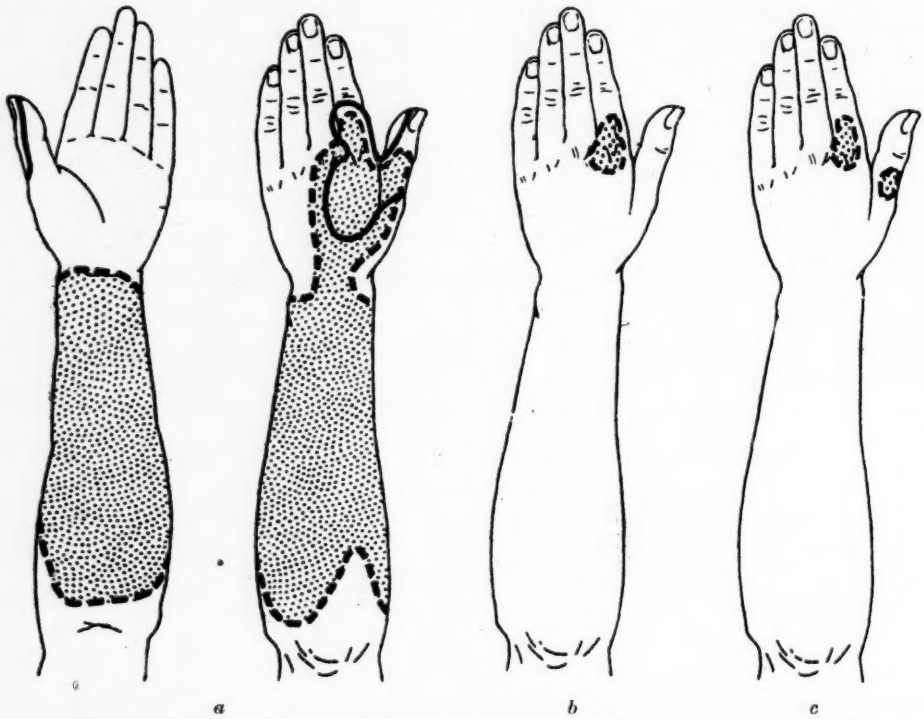

FIG. 392.—*Case* 19.—(*a*) Areas of epicritic and protopathic loss twelve days after reception of injury; (*b*) Condition fourteen days later than (*a*); (*c*) Condition fourteen days after operative division of nerve.

ON EXAMINATION, Sept. 27.—Wrist-drop was present.

Motor Powers.—All 'musculospiral' muscles fail to contract except triceps.

Sensation.—On pressure over track of projectile, paræsthesiæ are felt in thumb and index finger; epicritic and protopathic areas of loss as in *Fig.* 392*a*.

Electrical Reactions.—No contraction to faradism of paralyzed muscles; with galvanism, K.C.C. greater than A.C.C.

ON RE-EXAMINATION, Oct. 10.—A great change had taken place. All the epicritic sensibility lost was regained, and the protopathic loss was very much smaller (see *Fig.* 392*b*).

OPERATION, Nov. 1.—The nerve was found almost completely fibrous for nearly three-quarters of an inch, and adherent to the external supracondylic ridge. The fibrous portion was resected, and the nerve stretched and sutured.

ON RE-EXAMINATION, Nov. 14.—Sensory loss as in *Fig.* 392*c*; over this area of protopathic loss there was delayed desquamation of the skin, perfectly obvious at a glance.

In *Fig.* 392*a*—the first condition of the sensory loss found—the boundary of the area of protopathic loss was very well marked and definite, but the degree of pain-perception loss was not quite so profound outside the area of epicritic loss as inside it. The anatomical incidence of this loss shows clearly that its pathological basis was physical, not psychical.

As we have seen, the area of epicritic loss is such as one associates with division of the musculospiral and of either its external cutaneous branches or the musculocutaneous nerve, but the area of protopathic loss includes areas supplied by musculocutaneous, musculospiral, and internal cutaneous nerves. The musculospiral certainly was the seat of a gross lesion, as was proved by operation; but from the position of the wounds it was possible for the musculocutaneous, but quite impossible for the internal cutaneous, to have been injured. Moreover, the presence of loss of protopathic sensibility, with retention of epicritic sensibility, in the area supplied by these nerves in the forearm, quite negatives any ordinary injury to those fibres of these trunks which supply the skin of the forearm.

Fourteen days later the condition figured in *Fig.* 392*b* had obtained—i.e., merely a small area of protopathic loss on the back of the hand and index finger. Operation showed an almost complete fibrosis of the nerve distal to the point of origin of the external cutaneous branches. Re-examination fourteen days after operative division of the nerve disclosed the condition shown in *Fig.* 392*c*.

What then was the cause of the presence of the area of epicritic loss, and its subsequent disappearance? Obviously this loss could not have been due to the musculospiral lesion alone, for it was not present later even after complete anatomic division of the nerve by operation; the external cutaneous branches of the nerve were intact, and hence had no share in its production; there must therefore have been some temporary, if slight, interference with conduction of epicritic-sensibility subserving fibres in the musculocutaneous nerve. In the interval between the first and second examinations these fibres must have recovered their conducting powers. At the same time there disappeared the loss of pain-perception sensibility in the area in the forearm supplied in part by the musculocutaneous. But this condition in the musculocutaneous, whatever pathological basis it had, was quite different in its clinical manifestations from the lesions of nerves that we are familiar with; otherwise there could not have been this loss of protopathic, with retention of epicritic, sensibility in that part of the skin of the forearm supplied by the musculocutaneous nerve. At the same time, whatever this condition of interference with conduction in the musculocutaneous nerve was, it is evident that the same condition must have been present also in the internal cutaneous nerve, and most likely in the inferior external cutaneous branch of the musculospiral, but not in the median and ulnar nerves.

If we were asked to formulate a theory to explain this extraordinary sensory phenomenon, we would propose the following: Under certain unknown circumstances the passage of a projectile through the tissues of a limb, in close proximity to nerve trunks, and especially subcutaneous trunks, may produce in those nerve trunks a condition of temporary failure of conduction, which affects chiefly protopathic subserving fibres; probably also

the epicritic subserving fibres are affected, but to so small a degree as not to cause perceptible loss of this form of sensibility—except in such an area as the radial part of the dorsum of the hand in this case, where a certain number of epicritic subserving fibres have already in addition been cut off by a gross lesion.

The residual area of protopathic loss on the dorsum of the hand in *Case* 19, and that remaining after operative division of the nerve in its lower third, would seem not only to prove that such an area may exist with a lesion in this position, but also to be an extreme example of that dissociation of cutaneous sensibility that we have seen does often occur in this area with musculospiral division.

Case 50 (q.v.) is another almost exactly similar example of this phenomenon. Here, with division of the musculocutaneous and short saphenous nerves, besides the areas of epicritic and protopathic loss to be expected from such lesions, there existed in addition for one month after the injury a large area of pain-perception loss in the skin areas supplied by the external cutaneous branches of the external popliteal and the long saphenous nerves. Here again there can be no question of a functional condition. It is noteworthy that in both these cases the abnormal condition existed for almost exactly one month after reception of the injury, and that both happened to be examined at a much shorter interval after this reception than was so in the cases by far of the great majority of the nerve injuries of this series. It is possible that in the future more examples of this phenomenon may be noticed on examination of cases soon after the infliction of the injury.

THE TREATMENT OF INFECTED SUPPURATING WAR WOUNDS.

By RUTHERFORD MORISON, Newcastle-upon-Tyne.

In the *Lancet* of Aug. 12, 1916, I published a method of treating infected, suppurating war wounds, and claimed for it that in some cases sterilization of the wound could be accomplished at once, and that in the remainder the spread of infection could be checked and limited.

The treatment was described as follows:—

1. Under an anæsthetic, usually open ether, cover the wound with gauze wrung out of 1–20 carbolic acid, and clean the skin and the surrounding area with the same lotion.

2. Open the wound freely and, if possible, sufficiently to permit of inspection of its cavity. (In doing this special regard must be paid to nerve trunks and muscular branches of nerves, since the division of blood-vessels, excepting the largest, and of muscles themselves, does little harm as compared with that of the disability following nerve damage.) Cleanse the cavity with dry sterile gauze mops, Volkmann's spoon, etc., and remove all foreign bodies.

3. Mop the surrounding skin and the wound cavity with methylated spirit. Cotton-wool mops conveying the spirit are used for this purpose, and are introduced on forceps.

4. Fill up the whole wound* with the paste described in the footnote below. [*Footnote*: Bismuth iodoform paste ('Bipp') is made by Sergt. Hunter as follows: Iodoform, 16 oz.; Bismuth subnitrate, 8 oz.; Liquid paraffin, 8 fl. oz., or a sufficient quantity. The powders are mixed together in a mortar, and the liquid paraffin incorporated. The quantity of liquid paraffin required varies according to the bulk of the powders, the bismuth in particular being liable to a considerable variation in bulk. A sufficient quantity should be added to form a paste. It is then advisable to rub down the paste, in small quantities at a time, on a slab with a spatula, to ensure freedom from grit and dry particles of powder.] Dress the wound with sterile gauze, and cover all with an absorbent pad, which is held in position by sticking-plaster and a bandage. This dressing requires no change for days or weeks if the patient is free from pain and constitutional disturbance. Should, however, discharge come through, the stained part must be soaked in spirit, and a gauze dressing wrung out of the same applied as a further covering.

Re-dressing is very simply done. After removal of the old dressings the wound is covered with a dossil of wool soaked in spirit, and the sticky, dirty-looking discharge is wiped off the surrounding skin until it is clean. This is done with dossils of cotton-wool soaked in spirit and applied by forceps.†

At the request of Colonel Sir Berkeley Moynihan I add the present paper.

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* The only change made is that I do not now entirely fill the wound with the paste, but rub the preparation well into all parts of it with dry gauze, removing any gross excess.

† So far as I can at present judge, all infected discharge comes from the surface of the wound in the neighbourhood of the skin. The paste in the depths is clean and should not be disturbed.

Until clear guidance is offered by bacteriological research, no definite opinion can be given as to which of the above steps may be safely omitted; but the probabilities are that iodoform is the most active agent in the treatment.* For more than twenty-five years iodoform, like iodine, in spite of bacteriological discouragement, has maintained a reputation in surgery; and the value of Beck's bismuth paste in the treatment of chronic suppuration and sinuses has been for some years universally recognized, though no satisfactory bacteriological explanation of its action has been offered. The same danger of poisonous absorption is recognized as a possibility from the use of either iodoform or bismuth; but paraffin in sufficient quantity to make a thick paste appears to diminish this risk in both.

Though we have bacteriological proof that the discharge and dressings from some wounds are sterile after a first dressing, in the large majority both contain pyogenic organisms. In spite of this there is in these wounds an absence of the clinical signs of inflammation; there is no redness, heat, pain, or swelling, and generally fever is absent. The only explanation that we can offer is the belief that in these wounds the organisms are derived from the surrounding skin and the wound surface, and that the depths in which the bipp remains undisturbed are free from infection.

The fact is that the bacteriology of wounds is so difficult a problem, that it has not yet been solved, and until it is, wound treatment cannot be so entirely controlled as it should be by scientific guidance. Meanwhile the results we have achieved are to me so remarkable that, considering the present conditions, it seems right that no time should be lost in making them better known. My experience has been limited to infected wounds of at least some days' duration, because the patients have already been treated in and sent over from France. In the earlier stages of the war, when our treatment was limited to free drainage, irrigations, frequent dressings, hot fomentations, and ordinary surgical methods, the results were unsatisfactory and the prognosis was full of uncertainty. To-day we know that we are masters of the situation, because we have proved that septic wounds can be so treated as to require no tube drainage, that they can be closed by sutures so that, however deep and infected, they *may* heal by first intention, and that the dressings in all cases need not be changed for days or weeks. These are such strong statements, that I dare not offer them unless evidence in their support was overwhelming. It has been difficult for me to realize the truth; it must be still more so to convince any who have not watched cases treated in this fashion. Outstanding facts, however, are that in the Northumberland War Hospital no death has followed the treatment, and in the wards under my supervision no fresh infection, such as cellulitis or acute abscess, has developed after any operation conducted according to the directions laid down.

Recovery in *all* of the cases has not been uneventful, and in a few, perhaps four altogether, symptoms strongly suggestive of iodoform or bismuth

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* Since this paper was written, two papers by Drs. Louisa Garrett Anderson, Helen Chambers, and J. N. Goldsmith, M.Sc., Ph.D. (Reports to the Medical Research Committee), have been published in the *Lancet* of March 3, 1917. They deal fully with the clinical, bacteriological, and chemical effects of bipp.

poisoning developed; but in men suffering from multiple wounds, or with head and urinary complications, it is difficult to say how much of their illness is due to injury and how much to iodoform absorption. That iodine is absorbed in every case liberally treated with bipp is proved by the fact that free iodine was found in the urine of one patient next day; and iodide of potassium, in quantity roughly corresponding to the amount of dressing used,

FIG. 393.—Bismuth absorption. The patient had multiple deep wounds, including a bad compound fracture of the humerus, all of which were filled with bipp. Note the staining round the teeth and on the mucous membrane of the lip. Recovery.

is found for many days in all. This knowledge has taught us that iodine or bismuth absorption seldom does harm.

Our hospital case-notes have special reference to this question, under the headings:—(1) *Temperature*: A rise of temperature, apparently due to absorption, as nothing else could be found to explain it, was noted in some cases, and along with this there was alteration in (2) *Pulse-rate*: This was quickened. (3) *Emaciation*: In two cases with large multiple wounds freely

treated with bipp there was, in spite of good appetite, progressive emacia tion. (4) *Bronzing of the skin*: This occurred in the above two patients, along with (5) *Diarrhœa*: and (6) *Stomatitis*: *blue patches on the gums and in the mouth* (bismuth poisoning): These were noted in three cases altogether (*Fig.* 393). (7) *Nervous symptoms*: Apathy or delirium was noted in five or six of our cases, and these symptoms have, I learn, been observed by others (iodoform poisoning). (8) *Urine*: Presence of potassium iodide. (9) *Excessive discharge from the wound*: A few of our wounds have discharged profusely a slimy purulent fluid after the application of bipp, and this we regard as an indication for its removal and replacement by some other form of treatment, as it is especially in these cases that the troubles to which our notes refer have arisen.

In two of our cases the symptoms have been sufficiently serious to demand cleaning out of the wound, and this is an obvious duty if suspicion of poisoning approaches certainty. In three cases we have noticed dermatitis and pustules develop on the skin surrounding the wound, but this was never a serious drawback—though probably attributable to iodoform.

Although some wounds may heal by first intention—and we have experience of large pus-collections from both abscesses and cellulitis doing so—the rule is that they heal by cicatrization of granulating areas. All granulating wounds may be materially reduced in size by careful suturing. For this purpose our rule is to use thick sterilized interrupted silk sutures soaked in tincture of iodine and tied through drainage tubing (Stiles), as in *Fig.* 396. In very dirty wounds these sutures should not be applied too closely together; but no large gaps need be left. Wounds should be closed as far as possible without tension at the first operation and dressing. Before closing wounds it is desirable to cut away any portions of dead tissue; but as little interference as possible is even more essential where there is any chance of recovery.

When a dressing is removed after having been on for days or weeks, the first exposure of the wound may shock surgeons accustomed to see dry, clean, entirely healed wounds after their ordinary operations. It should however be remembered how long a time it required for these results to be obtained; and the surprise to some extent disappears so soon as the slimy purulent mass is cleaned away, and the condition of both wound and the skin surrounding it is investigated. The granulations are vascular and active, and the surrounding skin is soft, supple, and unsodden; and though the result may not be ideal, it is a promising advance on the frequent dressings and the free drainage which threatened to become the standard requirements of war surgery.

Fractures.—The most striking advantages of this treatment have been observed in cases of compound fracture of the long bones. Anyone with experience of war surgery knows the difficulties encountered in this class of case. The multitude of splints and dressings suggested to overcome them is the strongest evidence that no satisfactory method of dealing with them has yet been found. Our cases now give little or no more trouble than simple fractures. The wounds are cleansed, treated, and closed as described, and the splints and dressings are left unchanged from one to five weeks. It is the usual experience at the end of one month to find some union of the fracture, and the wound a superficial granulating area—or, in a few cases, entirely

healed. The absence of active sepsis diminishes the chance of bone necrosis, and the rapidity with which union occurs suggests that osteogenesis has been promoted by the treatment. All of these wounds have been treated as those in the soft parts are—namely, by free exposure of the fractured bone and the depths of the wound; removal of all dirt, foreign bodies, and entirely loose portions of bone; dry-gauze, then spirit-gauze, mopping; rubbing bipp into all parts of the wound, including the fractured portions of bone; and suture of the wound. The surrounding skin and the wound are then covered by gauze spread with bipp, and dressings and splints are applied.

Our splints are now very simple, and nearly all cases, including fractures of the femur, are treated with strips, cut to fit, of well-padded Gooch splinting. My colleague, Dr. Samuel Whillis, introduced a useful method of fixing and strengthening these splints by bands of plaster-of-Paris bandages, which we frequently use.

After union of the fracture has occurred, a sinus may persist, and at the bottom of this there is a piece of dead bone. Operation in these cases, before this treatment was adopted, often led to a septic flare-up and more necrosis from a fresh infection of the cut bone. In one of our cases, a fractured femur, I had performed five operations for the removal of sequestra following attacks of fresh infection from the operations, and could not obtain healing till the last occasion, on which the wound was bipped. Healing then promptly occurred, as is now the expected result in these previously troublesome cases. In all of them, after cleansing the wound, the cavity in the bone has been filled with bipp and the soft parts closed by sutures.

In my previous paper I suggested that bipp promoted phagocytosis; that it stimulated osteogenesis; that the antiseptic effects spread beyond the site of its implantation; and that it caused little harm to the tissues, offering explanations for my beliefs. A larger experience has confirmed all these conclusions. As further evidence of the fact that bipp does not readily destroy the tissues, we have now knowledge that it can be applied over skin grafts, and that the grafts will live and grow on granulating surfaces.

PARTICULARS OF CASES.

The following cases have been selected as examples of our methods and results, and visitors to the Northumberland War Hospital can support my statement that they are not chosen as exceptional.

Fractures.

Case 1.—Pte. B., age 23. Wounded Oct. 8, 1916, by a shell. Admitted to Northumberland War Hospital, Oct. 15, with a large irregular wound on the outer aspect of the left upper arm, about the level of the junction of the upper and middle thirds, 5 by 4 inches, and a small wound on the anterior aspect of the arm, same level, 2 by 2¼ inches. Both wounds discharging pus freely. Fracture of left humerus, about same level. Mobility of fragments marked. A good deal of swelling of upper arm and round elbow. Some œdema of hand. Movement of wrist-joint and of fingers present. No alteration in sensation of arm. On admission patient was wearing a straight Jones splint, with extension to hand. Dressing, eusol. *X* rays (Dr. Bunting) showed fracture of left humerus about 4 inches below head; lower end displaced forwards and inwards. Wide gap between the two fragments, bridged by only a few detached pieces.

OPERATION, Oct. 19.—Before a company of distinguished surgeons the wounds were explored, and an incision was made between the two, on to the posterior surface of the arm. Cavity cleaned. No loose pieces of bone found. Wound treated with bipp. Sutured. Put up with a pad of wool against chest.

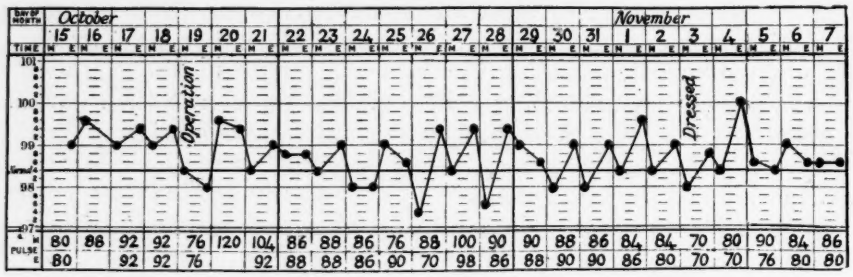


FIG. 394.—*Case* 1. Temperature chart.

DRESSED, Nov. 3 (15 days).—No signs of inflammation about wound. No discharge from depths. Wound where sutured had healed by first intention. There were two superficial granulating areas where skin edges could not be approximated.

Case 2.—Pte. S., age 39. Wounded July 29, 1916. Admitted to Northumberland War Hospital, Aug. 7, with a large lacerated wound, of left upper arm, 3½ by 4 inches, and compound fracture of upper end of humerus (*Fig.* 396).

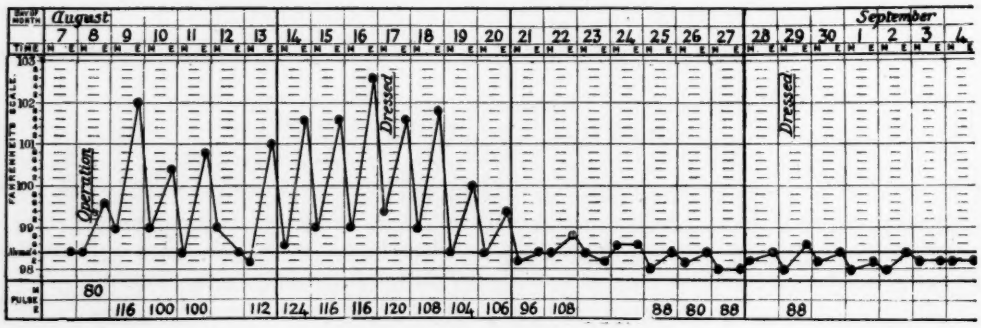
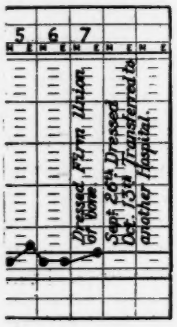


FIG. 395.—*Case* 2. Temperature chart.



OPERATION, Aug. 8.—Fracture of surgical neck of humerus could be felt through wound. Wound cleaned up and treated with bipp. Sutured with silk and silkworm gut (*Fig.* 397.)

DRESSED, Aug. 17 (9 days).—About a drachm of discharge on dressing. Sutures all holding. No pus to be squeezed from depths. Sutures removed. Re-dressed with bipp.

DRESSED, Aug. 29 (12 days).—Union in fracture. Small amount of discharge. Wound had stretched a little and was covered with healthy granulations. Re-dressed with bipp.

DRESSED, Sept. 7 (9 days).—Small amount of discharge. Granulating area smaller. Firm union of bone. Arm to be left in sling, not bandaged to side. Bipp re-applied.

DRESSED, Sept. 26 (19 days).—Wound apparently superficial. Granulations bled very easily. To be dressed every other day with spirit gauze.

Oct. 13.—Discharged to Australian Convalescent Hospital. Wound not quite healed.

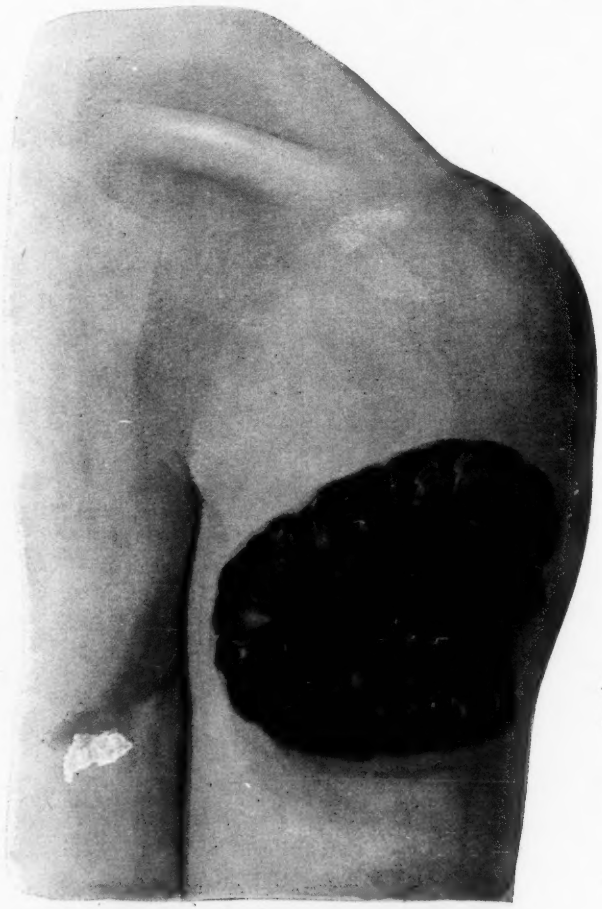


FIG. 396.—*Case* 2. The large granulating wound was formed by œdematous septic deltoid muscle, and was closed with considerable tension—a probable explanation of the rise in temperature during the early days.

FIG. 397.—*Case* 2. Wound after operation.

Case 3.—Pte. G., age 23. Wounded July 29, 1916, by shell. Admitted to Northumberland War Hospital, Aug. 2, with large jagged septic entrance and exit wounds on lower part of right upper arm (*Fig.* 398). No radial pulse. No sensation in hand. Very slight movement of fingers. *X* rays showed oblique fracture of lower end of right humerus, involving elbow-joint.

FIG. 398.—*Case* 3.
Wounds of upper arm before operation.

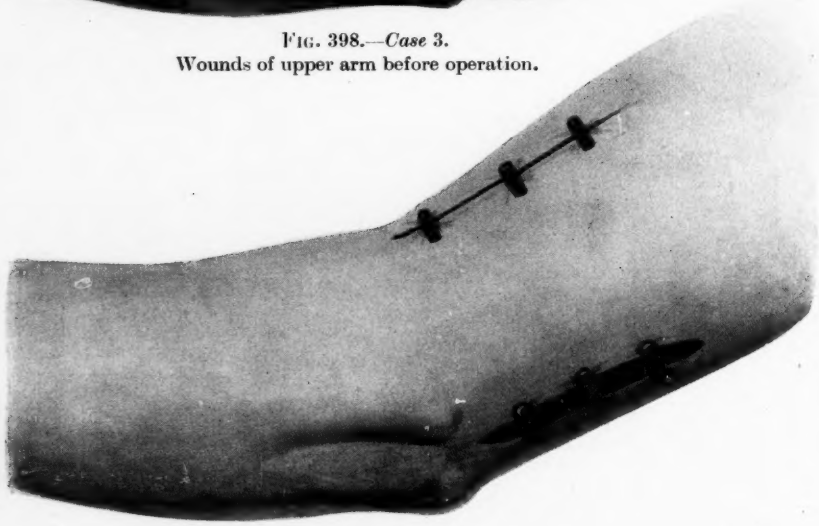


FIG. 399.—*Case* 3. Wounds after operation.

OPERATION, Aug. 4.—Wounds enlarged. Small piece of bone removed. Wounds cleaned, bipped, and partially sutured with silk and silkworm gut (*Fig.* 399).

DRESSED, Aug. 15 (11 days).—Large amount of discharge. No signs of inflammation. Sutures holding. Some removed and a small portion of bone taken out superficially.

DRESSED, Sept. 7 (23 days).—Fair quantity of discharge on dressing. External wound healed but for small granulating area about its centre. Remaining sutures

removed from this. Internal wound still showed fairly large superficial granulating area. Remaining sutures removed. Wounds re-dressed with bipp.

Firm union of bone. Some movement in elbow-joint, and improvement in fingers. Splints left off.

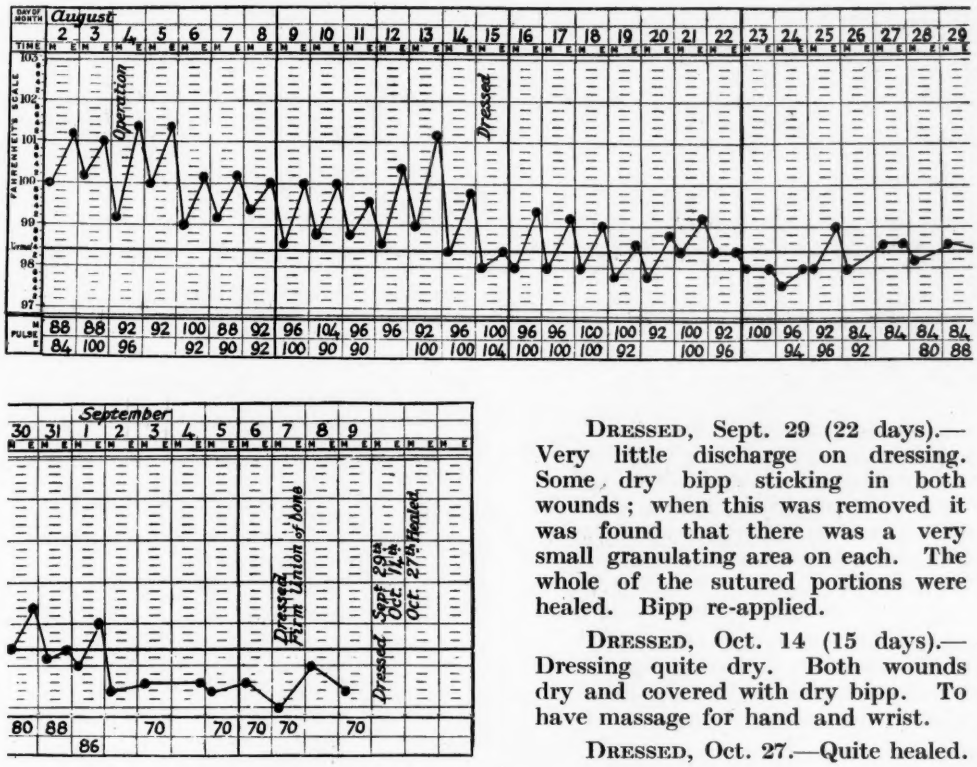


FIG. 400.—*Case* 3. Temperature chart.

DRESSED, Sept. 29 (22 days).—Very little discharge on dressing. Some dry bipp sticking in both wounds; when this was removed it was found that there was a very small granulating area on each. The whole of the sutured portions were healed. Bipp re-applied.

DRESSED, Oct. 14 (15 days).—Dressing quite dry. Both wounds dry and covered with dry bipp. To have massage for hand and wrist.

DRESSED, Oct. 27.—Quite healed.

Case 4.—Pte. J., age 27. Wounded Sept. 15, 1916, by shell. Admitted to Northumberland War Hospital, Sept. 18, with an irregular jagged wound over the ulnar border of the left forearm, 2½ by 2½ inches, with muscle exposed, accompanied by slight numbness of ring and little fingers and some loss of movement in the little finger (*Fig.* 401); and on the external surface of the left hip, above and external to the left anterior superior spine, an irregular, deep, sloughy, foul-smelling wound, 4½ by 3 inches, transverse in direction. The fractured crest of the ilium could be seen at the bottom of it. Ecchymosis round about (*Fig.* 403).

X rays showed:—Comminuted fracture of ulna 3 inches above wrist. No displacement; position good.

Hip.—Fracture of crest of ilium externally, with large gutter.

OPERATION, Sept. 19.—Wound of forearm explored. Comminuted fracture of ulna felt. One small piece of loose bone removed and several pieces of sloughy muscle. Wound cleaned and treated with bipp. Muscles which had been divided (extensor and flexor carpi ulnaris) drawn together with catgut mattress sutures; skin and subcutaneous tissues with silk and silkworm gut (*Fig.* 402). Two Gooch splints.

Wound over left hip explored. Some sloughy muscle and several pieces of spongy bone mixed with khaki removed. Long track found to burrow under gluteal muscles through ilium into pelvis. Wound cleaned and treated with bipp. Large

quantity of bipp put into hole in crest of ilium. Sutured with silk and tubing and silkworm gut (*Fig.* 404).

DRESSED, Oct. 5 (16 days).—

Arm.—About 1 oz. discharge on dressing. No signs of inflammation round wound. Sutures had given slightly—two silkworm-gut sutures had cut through one

FIG. 401.—*Case* 4.
Wound of forearm before operation.

FIG. 402.—*Case* 4.
Wound of forearm after operation.

side. Sutures removed. Wound was fairly deep and granulating, about 1 inch across at its widest part. Some necrotic-looking ulna could be seen in depths.

Hip.—About 2 oz. discharge on dressing. No irritation round sutures or wound.

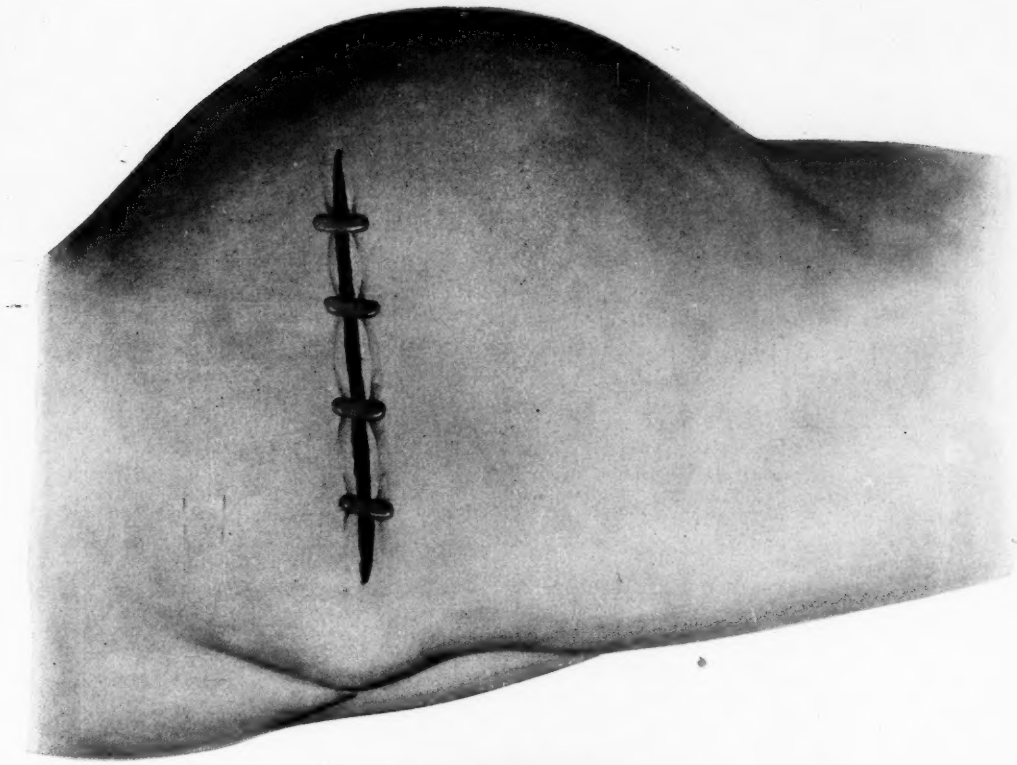


FIG. 404.—*Case* 4. Wound of hip after operation.

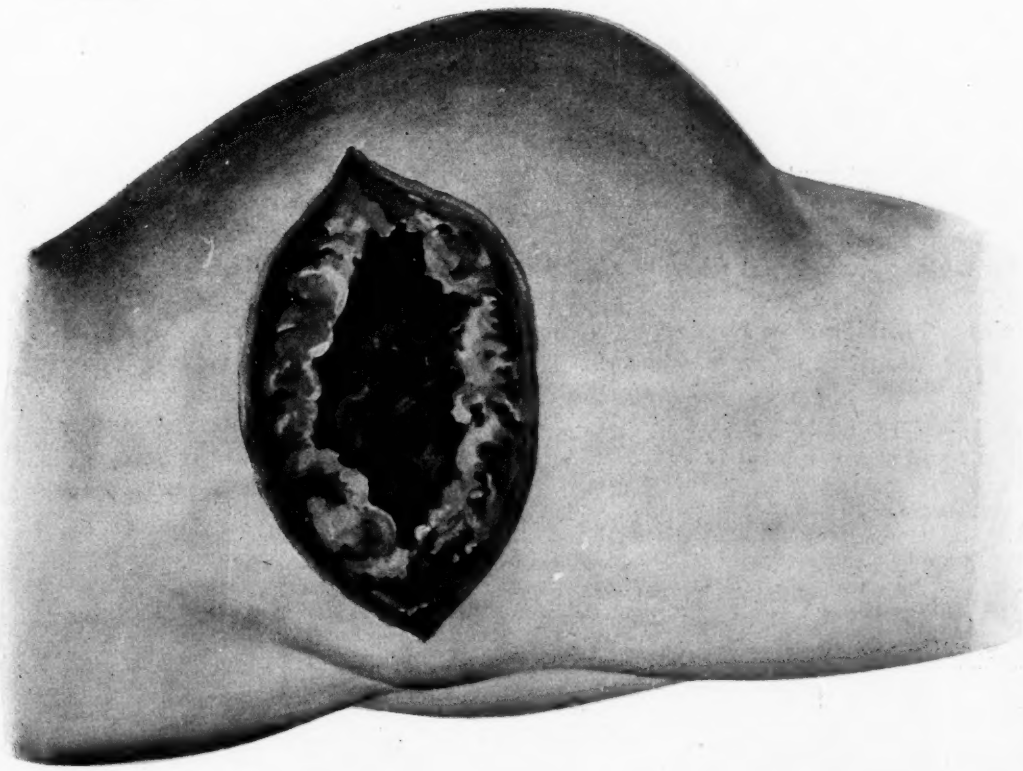
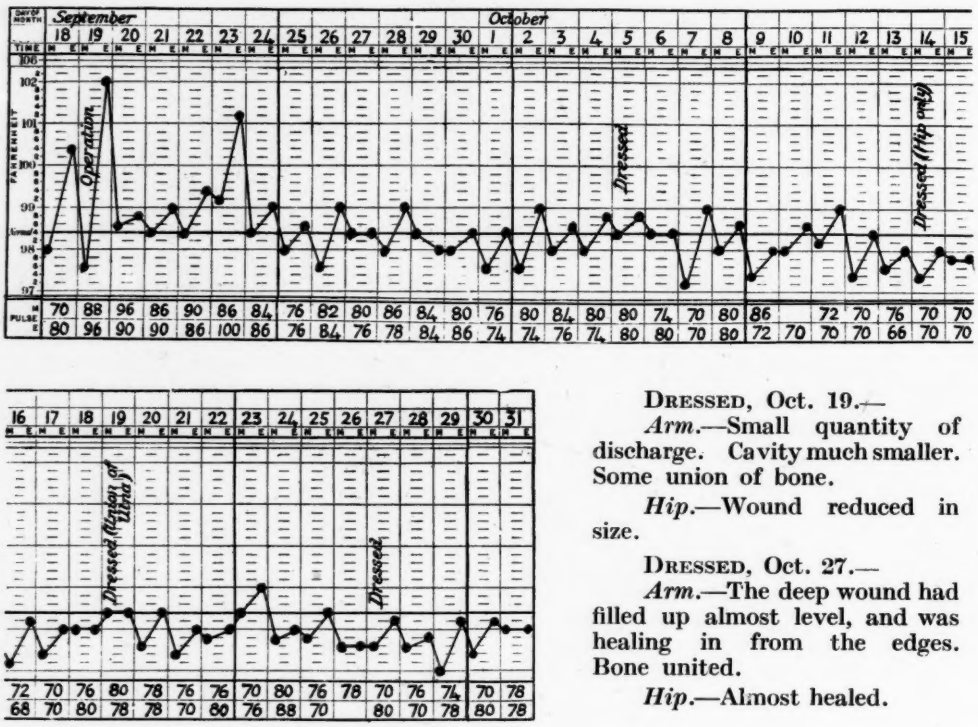


FIG. 403.—*Case* 4. Wound of hip previous to operation.

The silkworm-gut sutures had all cut through one side. Sutures removed. Wound a narrow granulating area, 1 inch at its widest part.

DRESSED, Oct. 14 (*Hip* only).—A narrow superficial granulating area, ½ inch at its widest part and 2½ inches long. To be dressed daily with spirit.



DRESSED, Oct. 19.—

Arm.—Small quantity of discharge. Cavity much smaller. Some union of bone.

Hip.—Wound reduced in size.

DRESSED, Oct. 27.—

Arm.—The deep wound had filled up almost level, and was healing in from the edges. Bone united.

Hip.—Almost healed.

FIG. 405. *Case* 4. Temperature chart.

WOUNDED JOINTS.

The treatment adopted for wounded joints differs from that of other regions. The joint should be freely opened and its purulent contents as far as possible evacuated by gentle squeezing. Then a quantity of bipp (about 2 drachms) should be ladled into the joint, the opening closed by interrupted sutures, and the medicament distributed by gentle massage of the closed joint. Washing or scrubbing, or any avoidable manipulation of the synovial membrane, must be carefully avoided. In cases where irretrievable damage has not been already inflicted on the bones and joints, it is possible to secure restoration of function in the joint (see *Figs.* 406 and 407); but in most, if the life and the limb can be saved, good work has been accomplished.

Case 5.—Pte. F., age 27. Wounded July 1, 1916, by shrapnel. Admitted to the Northumberland War Hospital, July 5, with a freely suppurating curved wound above and to outer side of left knee, sutured, and containing a large drainage tube. Swelling of knee-joint and great pain.

X rays showed a gutter in external condyle, involving articular surface.

OPERATION, July 7.—Sutures removed. Wound explored, and found to extend behind patella into knee-joint. Wound cleaned and treated with bipp, and sutured.

The joint was emptied by squeezing, a teaspoonful of bipp was put into it, and the joint massaged. Leg put up in two lateral Gooch splints with extension.

DRESSED, July 11 (4 days).—This dressing was done because patient had had evening temperature and some pain. Some pus from depths. No redness round sutures. Some swelling of joint. Re-dressed with bipp.

DRESSED, July 14.—A quantity of slimy purulent discharge on dressing. No pus from depths. Sutures had given way. No signs of inflammation.

DRESSED, Aug. 1.—Some discharge. Healthy granulations. Wound had contracted. Some painless movement in joint. Bipp re-applied.

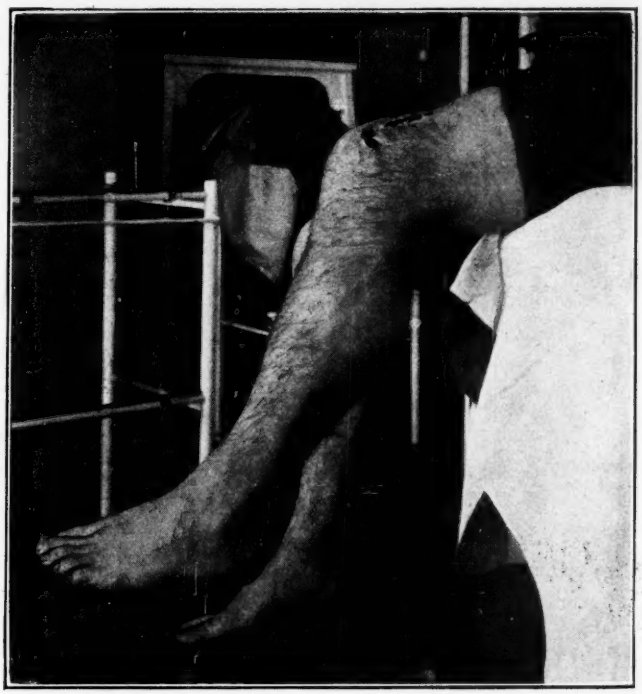


FIG. 406.—*Case* 5. Shows amount of flexion of knee-joint.

DRESSED, Aug. 11.—Slight discharge. Granulations smaller. Movement of knee increasing. Bipp re-applied.

DRESSED, Aug. 24.—Wound still contracting. To be dressed daily with boric lint.

DRESSED, Sept. 7.—Granulations much less. Movement in joint increasing.

DRESSED, Oct. 5.—Wound healed but for a narrow strip. Flexion to not quite a right angle.

Note.—No encouragement was given to him to use his joint, as the wound was not quite healed (see *Figs.* 406 and 407).

Case 6.—Pte. H., age 29. Wounded Aug. 7, 1916, by a bullet.

Note from No. 10 *C.C.S.*—"Entrance wound right knee, postero-external. Exit wound antero-internal. Head of tibia badly fractured and comminuted; excised. Irrigation with eusol. Glycerin-formalin 2 oz. into joint. Joint stitched up.

"22.8.16.—Temperature high. Joint explored. Lower part of wound opened up.

"26.8.16.—Skin flap opened up.

"30.8.16.—Opened completely. Joint cavity irrigated freely. Tubes put in for irrigation of joint cavity.

"3.9.16.—Has been treated by Carrel's method for last three days."

Admitted to Northumberland War Hospital, Sept. 12. Temperature 101·4°, pulse 120. Patient complained of great pain in right knee, and looked very ill. Taken to operating theatre and anæsthetized. Three drainage tubes were protruding from dressings, and were removed with the dressings, which were soaked with pus and had a very foul smell. A large irregularly oval wound, deep and sloughy, was exposed on the anterior aspect of the right knee-joint, 7 by 6 inches, and the gap between the tibia and femur could be seen freely exposed. External to this wound was a longitudinal, very septic, incision wound (*Fig.* 409).

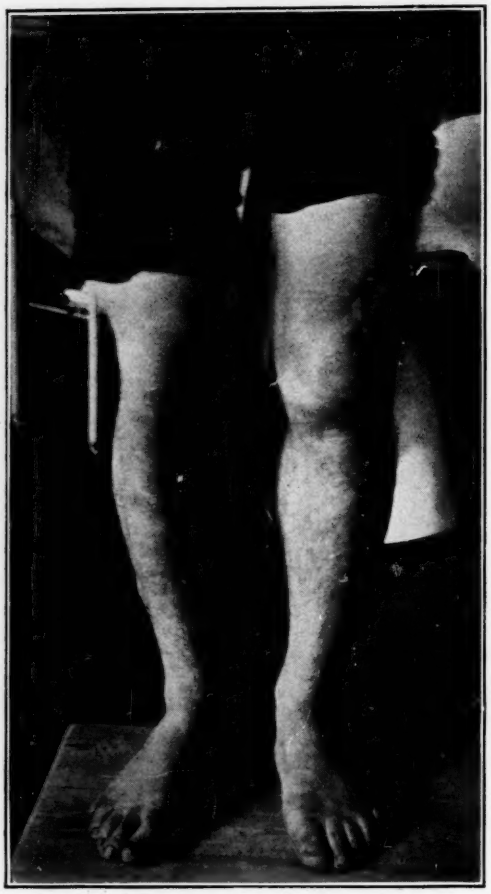


FIG. 407.—*Case* 5. Shows still unhealed wound on outer and front surface of knee-joint.

Whole area cleaned. Patella and external semilunar cartilage (remains of) removed. Tracks opened up. Whole treated with bipp, and closed with sutures as far as possible (*Fig.* 410). Leg put up in two lateral Gooch splints.

On the next day the patient was very comfortable. He stated that he felt easier than he had yet done since being wounded.

DRESSED (under anæsthetic), Sept. 26 (14 days).—Considerable quantity of discharge in dressing. Sutures all in position. Wound looked free from any inflammation. Sutures removed. No pus to be squeezed from depths. Re-dressed with bipp.

DRESSED (under anæsthetic), Oct. 13 (17 days).—Fair quantity of discharge in dressings. Wound looked clean. Several sequestra removed from outer head of tibia, and in connection with them a collection of pus on posterior aspect of thigh opened, cleansed, treated with bipp, and sutured. Re-dressed with bipp.

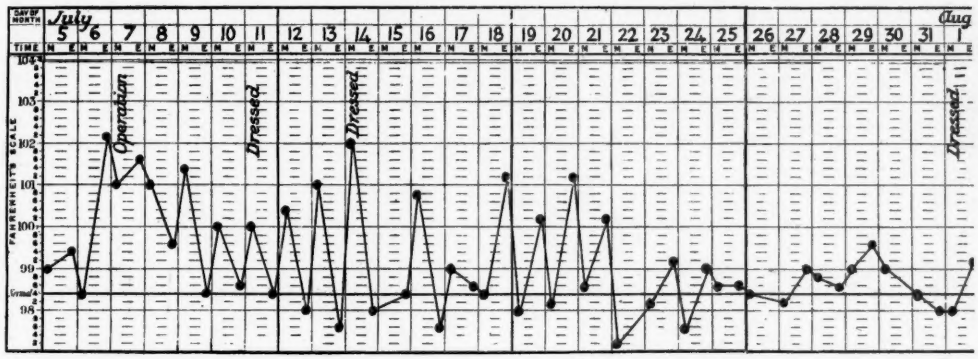
DRESSED (without anæsthetic), Oct. 27 (14 days).—Fair quantity of discharge in dressing, perhaps ½ oz. Granulations looking clean and healthy. A few drops of pus coming from the incision made on the antero-external surface. No signs of inflammation round sutures closing posterior incision on thigh, which was healed. Sutures removed. Some union found between tibia and femur. Re-dressed with bipp.

A short note of the following case, though not resulting from a war wound, will be useful as evidence of the value of the treatment advocated for infected bones and joints.

Case 7.—A girl, age 16, who was suffering from a suppurating blister on the right heel, was suddenly seized with a rigor and a pain above her right knee. Eleven

days later she was admitted to a private hospital very ill, with what was obviously an infective osteitis of the lower end of her right femur, and some effusion into her right knee-joint.

On Sept. 8 I opened a large abscess in the lower part of her thigh, and felt the femur bare posteriorly for 4 inches. After cleaning the abscess, I made a gutter in the femur for the length of the bare portion, scooped out the purulent medulla, and then cleaned and bipped the wound, filling the bone gutter with bipp, and closing the wound with interrupted sutures.



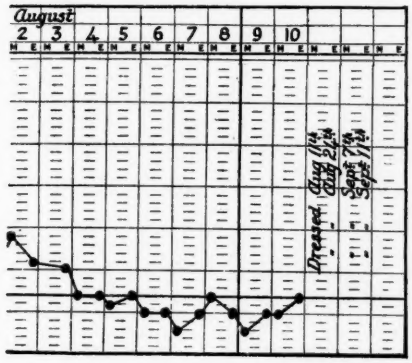


FIG. 408.—*Case* 5. Temperature chart.

The same night was the first occasion in which she had had any proper sleep since her illness commenced, and next morning she enjoyed her breakfast. The bad pain was entirely gone, and her general condition had so much improved, in spite of a nocturnal rise in temperature, that the wound was not dressed for eight days —when she was complaining much of her knee.

The joint was now found to be much swollen and tense. I opened it freely on the outer side, and squeezed out between 3 and 4 oz. of pus, put in 2 drachms of bipp, sutured the wound, and massaged the joint.

Three days later she complained of a sudden sharp pain in her left side, and shortness of breath. On the following day Dr. Walkinshaw discovered a patch of pleuritic friction over the painful area. All trouble shortly subsided, and her condition ceased to cause any anxiety.

When she went home there were still two small granulating areas, one—certainly superficial—over the outer side of the joint, and another—deeper, and probably leading to the bone which had been found bare—over the lower and inner end of the femur.

CEREBRAL HERNIA.

Before the introduction of this method of treatment, we dreaded cerebral hernias. If they recovered, the frequent dressings and profuse discharge from them necessitated extraordinary attention, and recovery was always very slow.

In all we have had five cases under our care since using bipp, and in all of them the diminished number of dressings and the recovery have been equally satisfactory, as the following notes show.

Case 8.—Pte. B., age 26. Admitted to Northumberland War Hospital, May 1, 1916, with a pulsating, septic, suppurating hernia cerebri, the size of a hen's egg, immediately above the left ear.

DRESSED, May 6.—With bipp.

DRESSED, May 13 (first time since bipped).—Hernia cerebri cleaner, and decreased in size by two-thirds.

FIG. 409.—*Case* 6. Wound exposing whole of knee-joint, before operation.

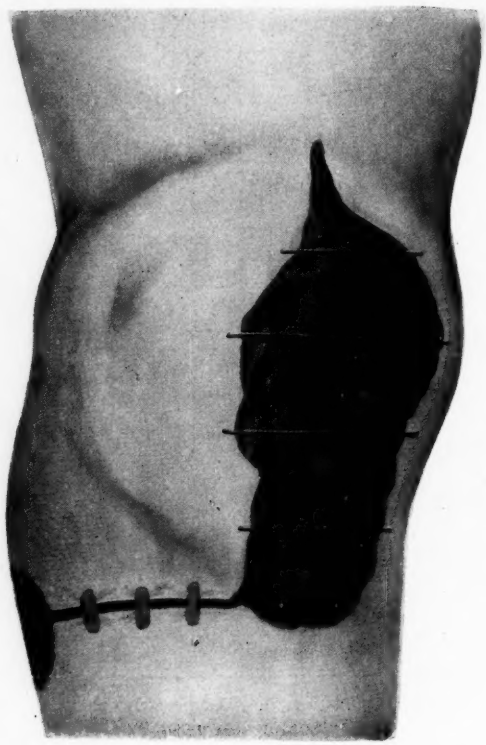


FIG. 410.—*Case* 6. Wound after operation. Note the sutures stretching over the granulations to help the closure of the wound. The wound closed below healed by first intention.

DRESSED, May 20.—Hernia nearly level with scalp. A little pus on skin round dressing, and also a very little lying in one sulcus.

DRESSED, May 26.—Hernia quite gone (20 days after first bipp dressing).

Case 9.—Pte. H., age 29. Wounded May 2, 1916, by a bullet. Admitted to Northumberland War Hospital, June 4, with a cerebral hernia on vertex of skull on left side, situated between the left parietal eminence and middle line, the size and shape of half a tangerine orange, and covered with a film of pus.

DRESSED, June 5.—Hernia dressed with bipp. Patient very ill, with bad cough and breathing difficult. Temperature 101°, pulse 136.

DRESSED, June 11.—Hernia decreased in size. Abscess formed at bottom of back, which was opened next day.

June 15.—Dullness over left base of chest, deficient breath sounds and râles over other part of chest.

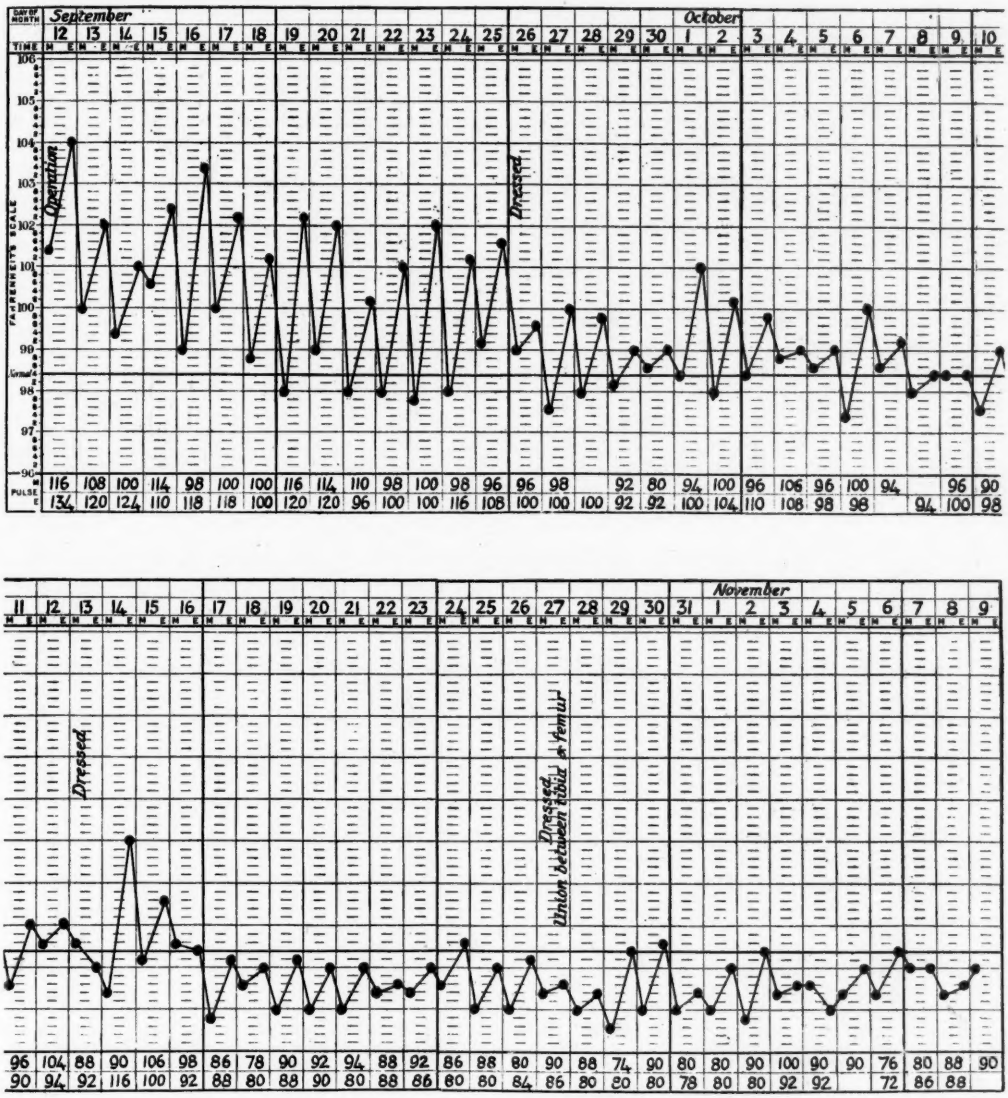


FIG. 411.—*Case* 6. Temperature chart,

June 20.—Very ill. Delirious. Empyema drained under a local anæsthetic. Patient very restless, and it was difficult to keep the dressing on his head. Restlessness and delirium continued till June 24.

June 26.—Hernia dressed. Still very large.

June 29.—Hernia quite gone (24 days after first bipp dressing).

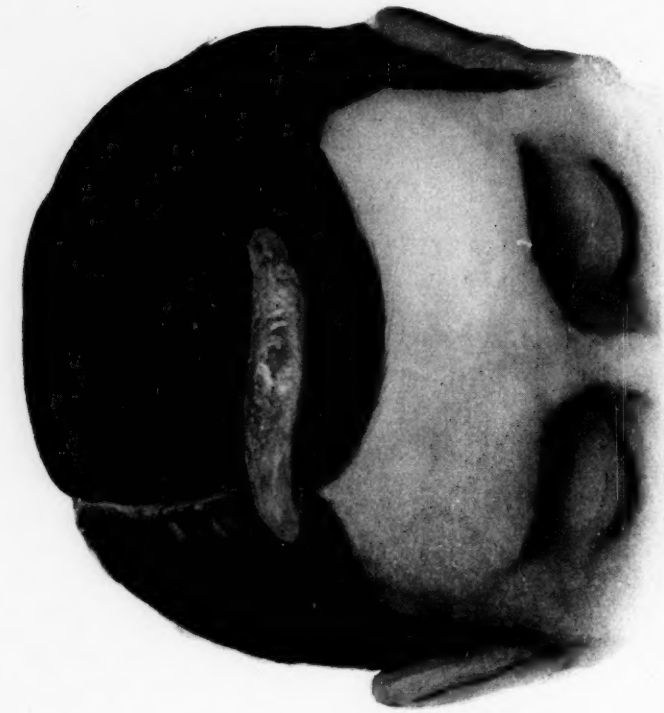


FIG. 413.—*Case* 10. The same hernia healed.

FIG. 412.—*Case* 10. A typical cerebral hernia on admission.

Case 10.—Pte. T., age 21. Wounded May 12, 1916. Admitted to Northumberland War Hospital, June 4, with a cerebral hernia, the size of a large hen's egg, on the middle and right side of the head, covered with a film of pus. Pulsation visible (*Fig.* 412).

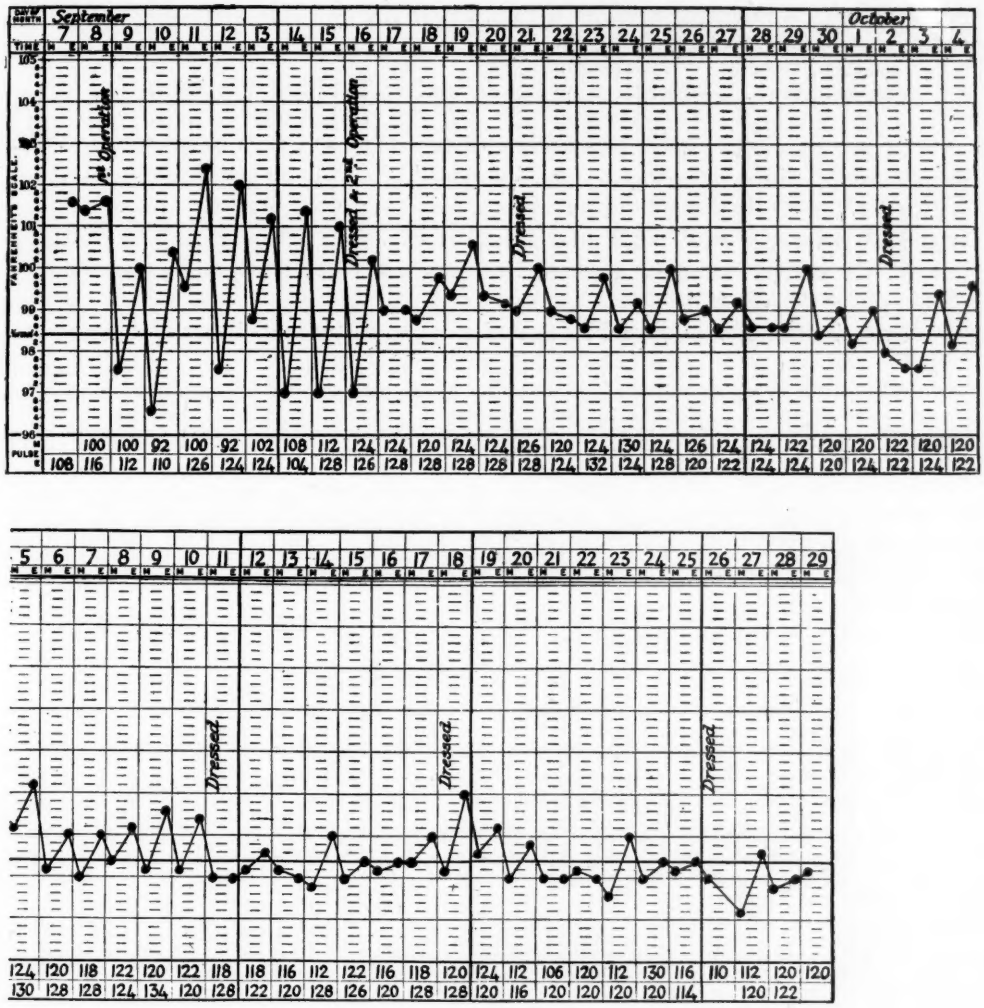


FIG. 414.—*Case* 7. Temperature chart.

DRESSED, June 5.—With bipp.
DRESSED, June 12.—Hernia decreased in size. Now size of a bantam's egg.
DRESSED, June 22.—Hernia slightly smaller.
DRESSED, June 29.—Hernia gone (24 days after first bipp dressing) (*Fig.* 413).

Case 11.—Pte. O'N., age 30. Wounded Sept. 18, 1916. Admitted to Northumberland War Hospital, Sept. 30, with a small cerebral hernia, the size of a cherry, protruding from the middle third of a horizontal, very septic wound about 3½ inches above the left external auditory meatus. Pulsation in the hernia and around it. Whole wound very tender.

Dressed, Oct. 4.—With bipp.
Dressed, Oct. 11.—Hernia no smaller.
Dressed, Oct. 20.—Hernia gone (16 days after first bipp dressing).

***Case* 12.—Sgt. P., age 28. Admitted to Northumberland War Hospital, Oct. 23, 1916, with a pulsating cerebral hernia, about the size of a small plum, over the upper part of the left frontal region.**
Dressed, Oct. 24.—With bipp.
Dressed, Nov. 5.—Hernia gone (12 days after first bipp dressing).

In my previous paper, the saving of trouble to nurses and orderlies was emphasized; since the work has increased, it has become apparent that without a larger staff it would have been impossible to carry on, if daily dressings had been the rule. The new method of treatment has not only saved painful dressings, limbs, and lives, but has been economical in labour and material for dressings.

I am indebted to Colonel Adams for leave to publish these cases.

A STUDY OF 1200 CASES OF GUNSHOT WOUNDS OF THE ABDOMEN.

By CUTHBERT WALLACE, C.M.G.,

Consulting Surgeon, British Expeditionary Force in France.

The expectant treatment of abdominal injuries was the method of choice in the armies of all the combatants at the beginning of the war. Gradually, on every side, the operative has replaced the older method. In the Lettsomian Lectures, 1917, I traced this change in treatment in the British army, and shortly described the method of examination, the injuries, and methods of dealing with them. The present paper is a summary of these lectures, together with some further analytical tables, and it is intended to serve as an introduction to articles by other surgeons dealing with the same subject.

Although it is very difficult to compare the results of the two methods, expectant and operative, some interest attaches to the figures obtained in the two periods respectively. The figures in the pre-operative periods had to be taken from the admission and discharge books of the field ambulances and casualty clearing stations, as no separate books were kept; consequently the figures could only be computed. In the second period special books were used, and the figures may be taken as approximately correct.

Mortality in the Pre-operative Days.—Into nine field ambulances over a period of six months there were admitted 1098 abdominal wounds, with 333 deaths—a mortality of 30·00 per cent. In the six casualty clearing stations during the same period there were admitted 131 cases of perforating abdominal wounds, with 73 deaths. From these figures it appears that the total mortality in the field ambulances and clearing stations was about 70 per cent.

There were also the deaths at the base in France to be added, and in the pre-operative days to which we now allude, many such deaths occurred which would, as far as can be judged, bring the mortality up to about 80 per cent. Makins gives the death-rate at the base among small-gut wounds as 84 per cent, and among colon wounds as 46·4 per cent in this period.

As showing the difficulty of arriving at accurate figures, it was stated by some people that 80 per cent of abdominal wounds recovered.

Selection of Cases for Rapid Evacuation.—The rapid evacuation of all abdominal cases to the casualty clearing stations puts a great deal of responsibility on the field ambulance officers. It is no light task to decide what cases can stand evacuation—in fact, it is one of the most difficult things that a medical officer is called upon to determine. Many patients, of course, are better for rest, and food and warmth; but in the case of abdominal wounds it must be remembered that hæmorrhage is a chief cause of death; and that the only hope for their salvation lies in the arrest of the hæmorrhage by

surgical means. It is therefore obvious that it is worth while taking risks in cases of abdominal wounds which it would not be right to take in other cases. There is also the danger of death from peritoneal affection, but experience has shown that the need for celerity on this account is as nothing compared to that necessary on account of hæmorrhage.

Relative Frequency of Abdominal Wounds.—The number of abdominal wounds admitted to the field ambulances and casualty clearing stations is known, subject to certain errors caused by the difficulty of accurately diagnosing a perforating abdominal wound. Since the onset of the operative treatment the errors, of course, have diminished. The number counted as perforating varied with each observer, and a surgeon who believed in the expectant treatment was inclined to reckon wounds as perforating which a believer in the operative treatment would have classed as non-perforating.

Percentage of Abdominal Perforating Wounds to Total Wounds.—The following figures were taken in certain casualty clearing stations by careful observers, but of different surgical persuasions, during a period in which the expectant treatment was paramount: (1) 1·88 per cent; (2) 1·5 per cent: (3) 0·75 per cent; (4) 0·62 per cent. If we take the statistics from nine field ambulances and certain casualty clearing stations over a period of six months, we get the following figures: field ambulances, 1·92 per cent; casualty clearing stations, 0·72 per cent.

The difference between the figures in the field ambulances and casualty clearing stations is accounted for in the following manner: (1) The field ambulance would naturally and rightly err on the side of making the graver diagnosis; (2) The mortality was high in the field ambulances, so that fewer cases reached the casualty clearing station; (3) At the casualty clearing station a more careful diagnosis acted in two ways: (*a*) It included some buttock, chest, back, and thigh wounds as abdominal wounds: (*b*) It excluded many cases of wounds of parietes. On the whole the effect was to lessen the proportion of abdominal wounds to total wounds. It is probable that, with the rapid evacuation, the number of abdominal cases that reach the surgeon has appreciably increased.

From these figures, which must be considered only approximate, one important fact stands out, namely, the relatively small number of abdominal wounds that a surgeon is called upon to treat.

Method of Recording Cases.—This paper is based on all abdominal wounds which reached an operating hospital from a certain sector of the line over a period of eighteen months. In forming an estimate of the mortality of abdominal wounds, and what can be done for them by operative treatment, it is necessary to include all the cases, no matter at what hospital they are treated. Results differ in different hospitals, more or less depending upon their distance from the firing line; they will also differ according to the nature of the fighting. Again, if times are quiet, there is plenty of time to treat all cases adequately and deliberately. At another time, when active operations are in progress, it may be only possible to pay attention to the most favourable cases. It is therefore necessary not only to reckon the operative mortality, but also to bring into account all cases which die without operation. This

has been done in the present series. In the case of the moribund, we have their numbers, but we do not in every case possess details of the injury.

The statistics were collected in the following way: Every hospital which was called upon to treat abdominal cases was provided with a book in which certain headings were written down, and these were filled in at the time of operation by the medical officers. These books were provided by the Medical Research Committee.

Comparative Mortality at Different Hospitals.—*Table* 1 shows the variations in results which may be obtained in different hospitals.

Table 1.

Unit	Mortality	
	Total	Operative
(1) A casualty clearing station	54·0	45·0
(2) „ „ „	72·7	—
(3) An abdominal hospital ..	36·4	—
(4) „ „ ..	82·6	48·8
(5) A casualty clearing station	50·0	44·4
(6) An abdominal hospital ..	56·4	52·6

Note: (1), (2), (3), (4) During same battle. (5) Same as (1) but in quiet time. (6) Same as (3) in a quiet time over a six months' period.

The Time Factor.—*Table* 2 was compiled by dividing the time between the receipt of the wound and the performance of the operation into two-hourly periods, and noting whether cases were sent to the bases or succumbed to their injuries. It mainly shows two things: (1) It gives some idea of the time in which cases are got out of the trenches and submitted to operation; and (2) It shows the effect on the mortality of the time which has elapsed between the receipt of the injury and the performance of the operation. It will be seen that most cases arrive some time between six and ten hours after the receipt of the injury. Up to six hours the chances are in favour of the patient; after this period they are always against him. *Table* 2a gives a list of a few cases in which patients have died after an unexpectedly short period, and also a few of those in which recovery has followed the lapse of a long period between the receipt of the wound and the operation. S[illegible] the limit of successful cases has been thirty-six hours for a resection of [illegible]all intestine, the same period for a suture of the colon, and the same fo[illegible] of the stomach.

Table 2.—591 Cases showing the Effect of Time on the Mortality.

	Hours	2	4	6	8	10	12	14	16	18	20	22	24 and over
To base..	..	3	30	75	55	34	19	7	4	11	4	0	27
Died ..	..	2	30	53	59	41	23	10	12	15	11	4	52
	Total	5	60	128	114	75	42	17	16	26	15	4	79

Table 2a.

To Base (Recoveries)		Died	
Hours	Injury	Hours	Injury or Cause of Death
24	Colon	6	Small gut and hæmorrhage
57	Bladder	6	,, ,, ,,
24	Sigmoid	5	Gas gangrene of abdominal wall
30	No visceral injury	3	Small gut and peritonitis
48	,, ,,	4	Stomach and duodenum
26	Jejunum	4	Small gut and hæmorrhage
15	Stomach	4	Stomach
65	Rectum—extraperitoneal	6	Multiple wounds of small gut
72	Colon fistula	3	Colon
		4	Spleen, excision of, for hæmorrhage

Nature of the Projectiles that Cause the Wounds.—

Bullets.—There are very many different kinds of bullets used in this war, and apparently their number goes on increasing. As is well known, the standard English, French, and German bullet is a pointed one. The English and German is a composite projectile which is liable to break up into mantle and core. The French bullet is much longer than either of the above, and is made of solid copper alloy. Although not liable to break up, it is liable to very great distortion. Naturally we are mostly concerned with the German projectile, which, as a rule, is pointed, but sometimes the old ogival-headed bullet has been extracted from wounds. All the modern pointed bullets are more unstable than the bullets of the Boer war. The instability is said to be most marked at the beginning and the end of the flight. In this war, where the fight takes place amongst houses, there are many opportunities for the bullet to be deformed and deflected. Again, the velocity and stability of a bullet is largely affected by passing through sandbags or a parapet, which, as a matter of fact, has to be something like 4 feet thick to be bullet proof. There is plenty of evidence that, whether from inherent instability or from hitting some object, the bullet does spin, and in several cases a bruised impress has been seen on the skin which could only have been made by a sidelong impact of the bullet. Again, in those cases where two legs have been wounded by the same bullet, the first leg has been perforated by a small standard track, and the opposite leg has suffered a large gaping wound, the obvious explanation being that the bullet in passing through the first limb was made to spin, and so caused a more extensive wound on the opposite member. A good deal has been heard about the explosive effect of the modern pointed bullet; and although one may say that it does cause worse wounds than the ogival-headed projectile, I am by no means persuaded that its so-called explosive effect is anything but a very rare occurrence. I am strengthened in this opinion by the study of accidental wounds, of which one sees a great number. Men are shot at all sorts of close ranges, up to actual contact, and yet, unless a hard bone is touched, it is not usual to get the explosive type of wound.

Shell Fragments.—These are, of course, of all sizes, but the fragments which are the cause of the abdominal wounds that the surgeon is called to

treat are generally not more than 1½ inches in the greatest diameter—usually a good deal smaller. There are different kinds of shells used, and some importance may be attached to the nature of the shell by which the man is wounded.

High-explosive Shells.—These shells may burst in the air, on contact with the ground, or after they have impacted themselves deeply in the earth. The velocity of the fragments into which the shell is blown depends on the disruptive charge, and the fragments under such a condition fly out in all directions. But the shape of the fragments depends largely on the type of shell—if the shell is segmented, the pieces are more or less quadrilateral; if not segmented, they are still often of quadrilateral shape, and have extremely sharp and ragged edges. Such shells, bursting on the ground, naturally become covered with dirt.

Shrapnel.—These shells usually burst in the air with a time fuse. They are of all sizes, and the leaden balls with which they are filled also vary somewhat in size. The penetrating power of such balls is due to the remaining velocity of the shell. The direction of the shrapnel balls will, as a rule, be downwards. In some cases a shell is apparently of a combined high-explosive and shrapnel type.

Bombs and Grenades.—In the early part of the war these bombs were often extemporized, and consisted of tin boxes filled with an explosive, scrap iron, cobblers' nails, and screws, etc. Nowadays they are made of iron, the surface of which is marked with grooves, so that on explosion they break up into quadrilateral fragments. Sometimes the force of the explosive will cause a bomb to burst into smaller fragments, often no bigger than a big matchhead. Although small, these fragments have—apparently from their high velocity—a very great penetrating power in the immediate neighbourhood of the explosion, though this is rapidly lost as the distance increases.

Trench Mortars.—Bombs from these are of various shapes, but consist essentially of a very large high-explosive charge with a comparatively thin containing envelope; they therefore very often burst into large ragged fragments as well as minute ones. They are generally timed to burst either on the ground or in the ground.

Bayonet Wounds.—These are very seldom met with, being usually fatal on the field. Mention may be made of two cases: In the first the bayonet penetrated the man's back and came out by his umbilicus; no viscus was injured, and the man succumbed to hæmorrhage. The second was the case of a man who was late in answering a challenge and was bayoneted by the sentry; the bayonet entered the left hypochondrium, wounded the greater curvature of the stomach, and entered the back wall of the abdomen; though promptly operated on, he died—not of his stomach wound, but of retroperitoneal sepsis.

Relative Number of Different Projectiles, and the Proportion Retained.—*Table* 3 has been drawn up with the intention of giving some idea of the relative frequency of the different projectiles met with in abdominal wounds; it also shows the number retained in the body. This table must be taken as only approximately correct for several reasons. In the first place, it is often impossible for a man to tell what hit him. In the second place, one cannot always be sure from a study of the entrance and exit wounds what was the

nature of the projectile; and again, many do not differentiate between high-explosive shell and shrapnel, the soldier generally including most shells which are not of a large calibre under the name of shrapnel. As a matter of fact there is very little difference in the nature of the fragments in high-explosive shells, bombs, rifle grenades, or trench mortars, if one excludes the larger fragments, with which we are very little concerned.

Table 3.

	Bullet	Shell Fragment	Shrapnel	Bomb or Grenade
Out ..	203	30	15	6
Retained ..	131	254	67	128
Total ..	334	284	82	134

Bullets.—Bullets and high-explosive shell furnish a large proportion of abdominal wounds. More bullets pass through the body than other projectiles; the reason for this is obvious. The causes for retention are not so obvious, and I have known bullets, fired at a comparatively short distance, remain within the body. In other cases the bullet may have passed through the earth, and so have had its velocity diminished. Ricochets account for a certain number.

Shells.—These show a high proportion of retention, which is obviously due to the shape of the fragments.

Bombs and Grenades.—The retained fragments are strikingly in excess of those passed out.

The large proportion of retained fragments at once suggests the possibility of armour; and no doubt armour could be devised which would keep out many fragments. It really is more or less a question of what the soldier is able to carry. One cannot help being struck with the resistive power of an ordinary book, as one has often seen projectiles arrested by such articles when carried by the soldier. The great saving of life effected by the steel helmet makes one hope that something may be produced equally efficacious in protecting the body. Although we could not expect such shields to be supportable and at the same time bullet-proof, yet the number of bullets is greatly outnumbered by shell and bomb fragments, which possess far less penetrative power.

Relative Mortality of the Different Projectiles.—The following table shows that bullets are but little less dangerous than shells, and that bombs and grenades are the least noxious.

Table 4.

	Bullet	Shell Fragment	Shrapnel	Bomb or Grenade
To base	91	105	15	60
Died ..	106	154	40	58
Total	197	259	55	118

General Incidence of Wounds. — The charts (*Figs.* 415, 416) were made by plotting the entrance wounds on the front and back of the body respectively. The wounds of the back form a substantial proportion of the whole. There is a tendency for the wounds to collect towards the sides, especially on the back of the body.

The comparative absence of mid-line wounds is also seen in *Fig.* 417, which represents the wounds in cases too bad for operation when they reach a casualty clearing station. This distribution is brought about by the presence in the mid-line of the spine and the great vessels. Men shot in these situations

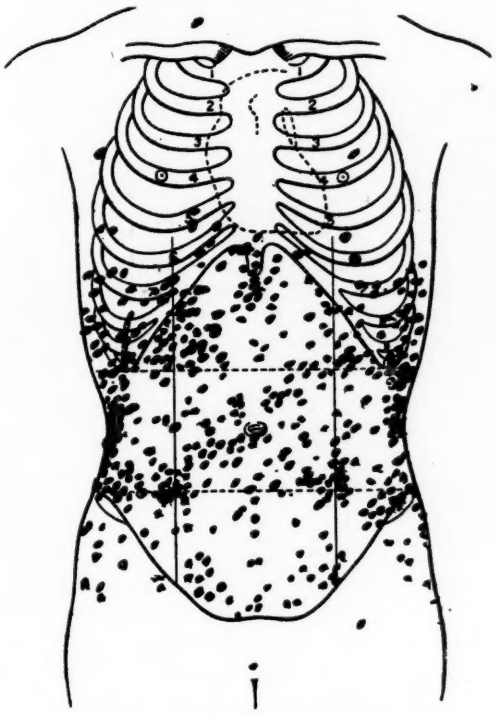


FIG. 415.—Regional incidence of wounds. Front view. 429 wounds. Mortality 53 per cent.

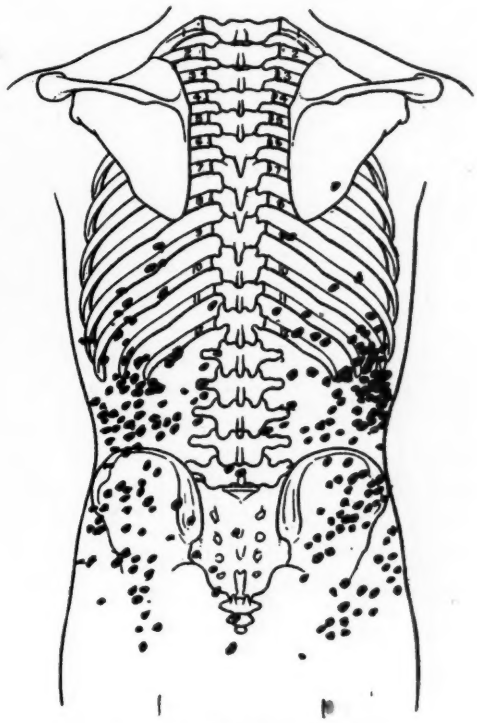


FIG. 416.—Regional incidence of wounds. Back view. 222 wounds. Mortality 60 per cent.

die on the field of battle. The collection of wounds towards the sides of the body may possibly also be caused by the fact that a man's front and back are more or less protected in the trench, while the sides of the body are open to enfilade fire. Many of the wounds on the back, especially those of the buttock, and thigh, are due to bombs and rifle grenades, a man instinctively turning his back to such a projectile in attempting to get away from it. The posterior wounds show a larger proportion of deaths than the anterior.

Influence of the Position of Wound and Direction of Missile on Prognosis. —

CASES TOO SERIOUS FOR OPERATION.—The chart (*Fig.* 417) was obtained by plotting the entrance wounds and the track of the bullet, when known,

in those cases which arrived at the casualty clearing station in such a condition as to preclude any operative procedure; they all died. It is rather striking to notice how the chart becomes blackened in a fan-shaped area, the apex of which is the left hypochondrium. Again we have a comparative absence of mid-line wounds and of hypogastric wounds. This must not be taken as meaning that hypogastric wounds are not dangerous, but only that they do not cause such injuries as to render operation useless. The side-to-side wound would appear to be the most dangerous among wounds that reach an

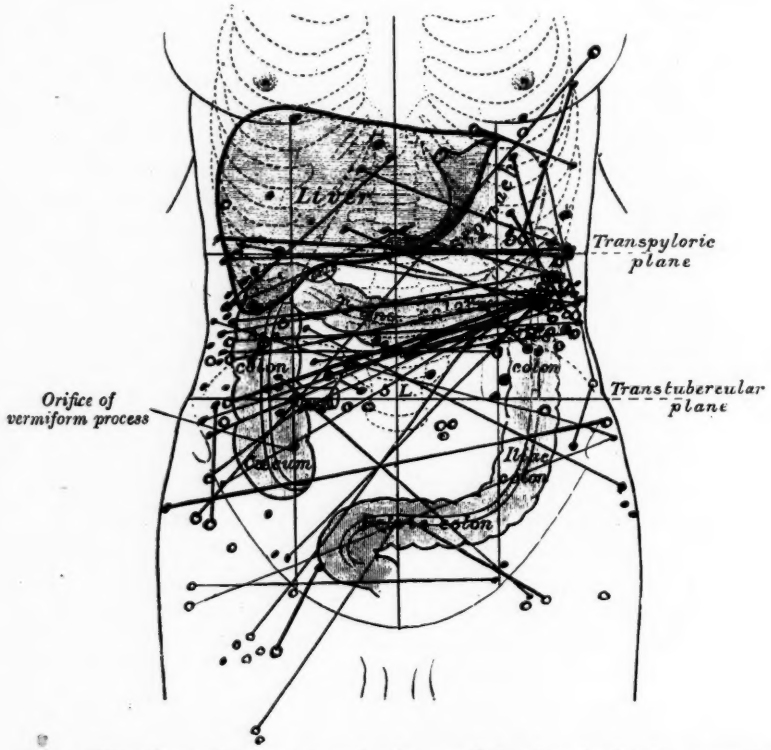


FIG. 417.—Chart of cases too seriously wounded to be submitted to operation, all being fatal. A black dot represents an anterior wound, a circle a posterior wound; the track of the projectile is shown by a line.

operating unit. This seriousness was noticed in the South African campaign. In 68 cases a post-mortem was performed; *Table* 5 shows the injuries, and *Table* 6 the number of times individual organs were hit.

In nearly every case there was much blood in the abdomen, and in 13 cases the note is made that death was due to hæmorrhage. In only 5 cases is shock noted as the cause of death: (1) One perforation of ileum with a shattered os ilium; (2) Multiple wounds of small gut; no blood in belly; (3) Shock; no other details; (4) Wound of ileum and sigmoid; peritonitis and shock; (5) Wound of rectum and small gut. In one case retroperitoneal sepsis was noted as the cause of death. In only three instances was peritonitis deemed the cause of death. The number of times the small gut was injured is the salient feature in the series, and perhaps another interesting

point is that the stomach figures five times. Wounds of the solid organs were responsible for death in twelve instances.

Table 5.—Showing Injuries in Moribund Cases.

Stomach and kidney	.. ..	2	Liver and spleen 2
„ „ colon	.. ..	1	Liver and kidney 1
„ „ liver	.. ..	1	Spleen and kidney 1
„ kidney, spleen, and pancreas		1	Bladder 3
Small gut	.. .. ..	27	Paraplegia and acute dilatation of stomach 1
„ „ and colon	.. ..	4	Prolapse of stomach, small gut, and colon .. 1
„ „ „ rectum	.. ..	2	„ „ colon, and spleen 1
„ „ embolism from wounded carotid	.. ..	1	„ small gut 1
Colon	.. ..	5	„ spleen and splenic flexure 1
„ and kidney	.. .. ..	1	Wound of internal iliac vein .. 1
Rectum	.. ..	2	
Liver	.. ..	8	Total Cases .. 68

Table 6.—Showing the Number of Times Individual Organs were Wounded.

Stomach	.. 5	Kidney	.. 5
Small gut	.. 34	Rectum	.. 4
Colon	.. 10	Bladder	.. 3
Spleen	.. 4	Pancreas	.. 1
Liver	.. 13		

In the chart (*Fig.* 417) are a good many buttock wounds. From experience gained in operating on such cases, we must regard lesions of the pelvic vessels as a frequent cause of death. The low horizontal level of the maximum-fatality area seems to show that combined thoracic and abdominal wounds are not immediately fatal, though some observers think that the combination is very fatal after operation.

Some curious instances of side-to-side wounds may be of interest: (1) A wound of the upper pole of the left kidney and lower pole of the right, wound of ascending colon, paraplegia; fatal. (2) Wound of the right kidney and spleen, vertebra penetrated; no paraplegia; fatal from splenic hæmorrhage. (3) Spleen torn to its anterior edge, left kidney perforated through its centre, upper pole of right kidney destroyed; fatal (bullet). (4) Wound of the left kidney and the posterior surface of the ascending colon; fatal. (5) Hepatic and splenic flexures alone wounded; fatal.

Cases Recovering without Operation.—*Fig.* 418 was obtained by plotting the entrance wound and the track of the bullet, when known, in cases that recovered without operation. Most of these wounds lie within the liver area. The chart also shows wounds in various other parts of the abdomen; and the explanation of their recovery, as will be seen later, is most probably due to the fact that the hollow viscera had escaped although the abdomen had been penetrated.

Wounds above the Transpyloric Plane.—Wounds in this region are among the least serious of all abdominal penetrations. Side-to-side wounds are, however, serious, especially if they are far back. Wounds which enter

the abdomen from above downwards such as are described as vertical, are also serious. Sometimes one has great surprises, however; and one case may be mentioned in which a soldier was shot accidentally by a revolver bullet which entered above the blade-bone and was taken out of the gastrocolic omentum; no hollow viscus was injured, and the man made a complete recovery.

Epigastric Wounds.—In the mid-line true anteroposterior wounds are seldom seen in hospital. The lesser curvature, the œsophagus, and a large portion of the stomach lie within this area.

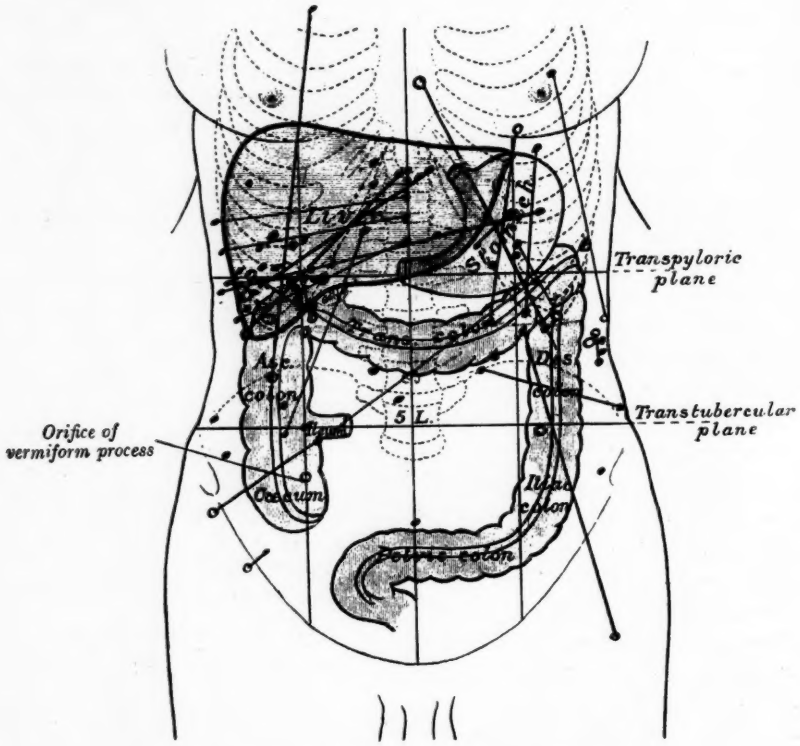


FIG. 418.—Chart of cases that recovered without operation.
Dots, circles, and lines have the same significance as in *Fig.* 417.

Wounds in this region are usually accounted as stomach wounds, and recovery is often reckoned as an instance of spontaneous healing. Operation has proved that in some cases the projectile misses the stomach and perforates the gastrohepatic omentum. Naturally, wounds in this region will often involve both surfaces of the stomach. Epigastric wounds have not maintained their reputation as favourable lesions.

Anteroposterior Hypochondriac Wounds.—On the right the liver will be perforated; on the left the cardiac area of the stomach as well as the greater curvature. Towards the lateral line of the body, the kidneys, spleen, and splenic flexure will be involved. As far as the liver and stomach are concerned, they are liable to a similar wound to that met with in the epigastric region.

Oblique Epigastric and Hypochondriac Wounds.—When the wounds are oblique from side to side, no distinction can be drawn between the two regions, as projectiles traverse both. These wounds are decidedly more dangerous than anteroposterior wounds. Indeed, they become more fatal as they get more oblique. On the right side a greater length of liver is traversed, and the dangers of hæmorrhage and sepsis are increased. On the left the stomach is perforated more and more obliquely, until a point is reached when the axis or flight of the bullet becomes parallel to the anterior wall or greater curvature. The result is either a long slit or a double hole through which the contents leak freely. The spleen, kidney, and splenic flexures will also at times be involved with the stomach. Wounds of the kidney and spleen are a fairly common combination; of the stomach and spleen a rare one.

Vertical Epigastric and Hypochondriac Wounds.—These are nearly always more or less inclined downwards and inwards, but cases occur of almost vertical wounds in which both the entrance and exit wounds are on the injury surface of the body and almost vertically above one another. When a projectile passes in those directions, the injury of the liver or stomach is complicated by one of the colon or small intestine, for the missile often passes below the transpyloric plane. In one such case both the antrum of the stomach and the transverse colon were almost completely cut in two. Vertical wounds on the lateral surface of the body appear at first as thoracic. On the right side they are not so dangerous, since they only traverse the liver; but on the left they may wound the stomach, spleen, and liver.

Posterior and Lateral Wounds of Hypochondriac Regions.—As usually met with, these are single entry wounds. Such wounds between the two axillary lines often exhibit one omentum protruded through the ribs. On the left, the spleen, kidney, and the splenic flexure may be wounded, and therefore such wounds are more dangerous than those occurring on the right. They are difficult to treat, as access to this region is not easy, and the infiltration of the retroperitoneal tissue renders detection of the colon perforation difficult even if the spleen and kidney are successfully dealt with. Posterior wounds in the costovertebral angle, or through the lower ribs, cause similar injuries to those on the lateral body surface.

Wounds between the Transpyloric and Intertubercular Planes.—This region is a very fatal one. Above the umbilicus the injuries resemble to a considerable degree those met with above the transpyloric plane, but below the umbilicus we have largely to deal with small-intestine injuries.

Anteroposterior Wounds.—Again these are seldom met with in the middle line. On either side of the spine, in the upper part of the region, perforations through the transverse colon are met with, and are usually easily dealt with. Lower down, but still near the middle line, the small intestine is wounded, and the gravity of the cases at once rises. In the lumbar region, wounds of the ascending or descending colon are encountered. If the peritoneal surface alone is involved, the danger is not so great, provided no large destruction of the wall has taken place. Wounds of the left lumbar region are more dangerous than those on the right, for here the coils of the jejunum overlie the great bowel.

There is another point of interest about flank wounds, and that is the possibility of the escape of the colon or peritoneum from injury owing to the

thickness of the muscles of the abdominal wall at this point. As a matter of fact the colon when seen from the front lies further from the lateral line of the body than might be supposed.

Wounds entering the back in this region are more fatal on the whole than those that enter the front; not only do they wound the viscera, but they plough up the retroperitoneal tissue, or cause it to be stripped by blood infiltration. When such a course is taken by a bullet or small shell-fragment, the external wound may be insignificant, but a hidden leak into the retrocolic tissue may cause death before sufficient relief has been given by a free incision or a colostomy.

Wounds below the Intertubercular Plane.—These include wounds through the hips, buttocks, and thighs. All are very serious.

Anteroposterior Wounds.—In the hypogastric region these are dangerous on account of small-gut lesions. Mid-line wounds frequently come to operation, as there are no great vessels to cause death before hospital is reached. If the bladder is full it will be involved, but it is a somewhat remarkable fact that such injuries are not very common. The pelvic colon and the rectum may be injured. Towards the side of the body, in the iliac regions, wounds of the cæcum and iliac colons are encountered.

Side-to-side Wounds.—These may involve the cæcum, small gut, and pelvic and iliac colons. Such injuries are very dangerous, the small-gut wounds being nearly always multiple. The pelvic vessels may also be injured, and cause death from direct hæmorrhage.

Semivertical Wounds.—In *The Lancet* of Dec. 18, 1915, I called attention to the dangerous nature of these injuries, and many have since confirmed this opinion. They are caused by missiles which enter the buttock, perineum, or thighs. In the early days of the war a wound in the buttock or thigh was often unconnected in the surgeon's mind with the possibility of an intestinal lesion; these wounds are nearly always accompanied by multiple wounds of the small intestine. The bladder and rectum are also often involved; such wounds are nearly always accompanied by pain in the abdomen soon after their receipt. The soldier often thought that he had been hit in the abdomen, while the surgeon was not inclined to accept this diagnosis; the fatality of such cases used to be partly due to the abdominal injury being overlooked, and time lost.

Possibility of Escape of Viscera in Penetrating Wounds.—It has always been a much debated point as to whether a projectile could traverse the peritoneal cavity without wounding the hollow viscera. Makins held that it was possible from his experience in South Africa. Others denied the possibility. There has never been any doubt that the liver and kidneys could be damaged without involving other organs. The point that required settling was as to the escape of the stomach in the upper part and the small intestine and colon in the lower. Those who believed in treating abdominal wounds by rest and starvation pointed to cures, by this means, of patients in whose cases it appeared, by a study of the track of the bullet, that a hollow viscus must have been perforated. Makins held that there was a possibility of recovery in cases of colon injury, but that small-intestine lesions were always fatal.

Until quite recently, when cœliotomy became the routine treatment of abdominal wounds, a proof that such escape was possible was almost wanting. The classical case of Cheatle's was often quoted as a proof, but there were people who were not convinced by it.

Fig. 419 shows a chart of cases in which the abdomen was opened and explored and no hollow viscus found injured. The abdominal cavity was usually full of blood. This blood came from two sources: (1) The vessels of the omentum, mesentery, or abdominal wall (deep epigastric usually); in these cases the hæmorrhage was arrested by ligature of the vessel; (2) From

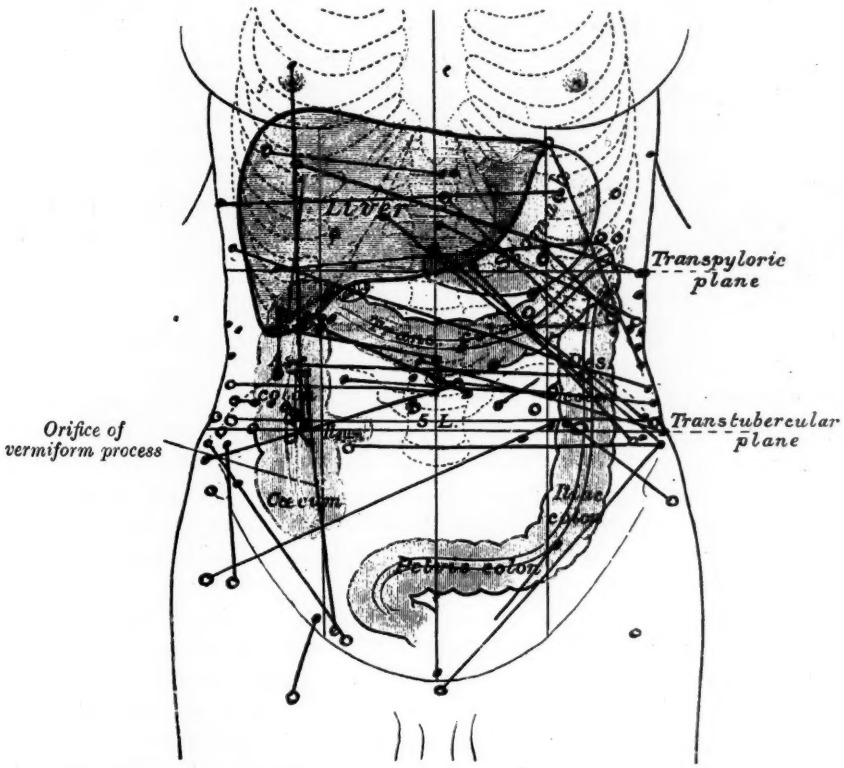


FIG. 419.—Chart of cases in which cœliotomy was performed and no hollow viscus found injured. Dots, circles, and lines as in *Fig.* 417.

cracks in the peritoneum raised by a retroperitoneal effusion of blood; here little beyond clearing the abdomen could be done, for experience has shown that such collections of blood are best left alone. In one case that deserves mention the vena cava was torn and was ligated; the patient survived ten hours.

In many cases there were bruising and tears of the peritoneal and muscular walls of the stomach or intestine. These tears and bruises explain the cases where a fæcal fistula or an intraperitoneal abscess has appeared some time after the receipt of the wound.

The Possibility of Spontaneous Recovery after the Perforation of Hollow Viscera.—It is quite true that people do recover spontaneously after wounds of the hollow viscera, but the number is very small. Those that recover may be said to be the exceptions that prove the rule. The following are instances :—

1. Healing of stomach. Makins (*Journal of Royal Army Medical Corps*, January, 1916) describes a case in which a wound of the posterior surface of the stomach was firmly sealed to the pancreas and spleen ; death resulted from secondary hæmorrhage.

Lieutenant-Colonel T. R. Elliot and Captain Henry have also described cases of spontaneous healing. I myself have seen a healed wound of the stomach in a patient who succumbed to other injuries. Lastly, Captain Green-Armytage actually closed the abdomen in a case where a hole in the stomach was impossible of suture, and a cure resulted. Although such healing does result, it must be looked upon as more of academic than of practical interest. No surgeon would nowadays use such cases as an argument in favour of abstention.

2. There have been frequent instances of recovery after wounds of the vertical colons, as has been insisted on by Makins, who attributes such a favourable result to the intense local reaction produced by the contents of this portion of the bowel.

3. For the history of the following remarkable case I am indebted to Surgeon-General Bowlby and Captain Bell.

A soldier was shot from side to side through the body at the battle of Loos. He was not operated on, and recovered. As far as I know, there was nothing special about his convalescence. He was again shot in the abdomen in the battle of the Somme, and was operated upon. When the abdomen was opened, several perforations of the small intestine were found in the neighbourhood of a mass of adhesions. The wounded and adherent segments were excised, and the man made a good recovery.

On slitting up the inherent coils, an entero-enterostomy was found between two adjacent loops ; in addition, there were several small herniated diverticula of the mucous membrane, obviously pointing to closure of the previous penetrations. This case is of interest because the process of healing corresponds to that which Captain Drummond has shown to be the case when the intestines of rabbits are perforated, and put back without suture. The herniated mucous membrane remains herniated, and gradually becomes covered with a layer of lymph, which slowly organizes and seals the hole, the herniated mucous membrane still forming a diverticulum.

Rupture of Viscera Outside the Actual Course of the Projectile.—

1. As in civil life, one meets with a fair number of abdominal injuries caused by horse kicks. Others are caused by falling-in of dug-outs, by burial of men by shell explosions, and by blows of fragments of wood which are hurled about. They present nothing out of the common, and the injuries seen are the same as some in civil life.

Captain Haycraft had one case which may be mentioned, in which the post-mortem examination on a man who died after burial showed numerous contusions of the small intestine, without rupture.

2. Similar injuries are caused by large shell fragments, usually shell caps, and several cases of the latter injury have been seen in which rupture of the intestine was accompanied by extensive contusions. Some years ago Makins wrote a paper on this subject, and he came to the conclusion that such injuries are caused by the bowel being caught between the unyielding posterior abdominal wall and the oncoming object. This supposition, I think, is strengthened by the association of bruises along with perforations in the case above quoted.

3. *Rupture of Solid Organs by Indirect Violence of a Passing Projectile.*—Such injuries are by no means uncommon. Kidneys have been found in which many cracks in the capsule were produced by shell fragments which did not themselves touch the organ. I have also seen two cases of ruptured spleen; the left lower chest was hit and the ribs broken in both. In one the diaphragm was intact, but on opening the peritoneum much blood escaped and there was an extensive tear in the spleen. In another case the diaphragm was ruptured over a small area, the blow being a glancing one. There was a corresponding wound on the outer surface of the spleen, and from this wound there ran in all directions radiating fissures in the capsule, showing that the spleen had been burst by the indirect blow it had received.

4. *Cases in which the Viscera are Damaged by In-driven Bone Fragments.*—

a. There are many cases of injury to the liver and spleen by the driving in of fractured ribs.

b. The cæcum, the ascending and descending colon, and also the small gut in the pelvis are all apt to be injured by small bony spicules driven in through the peritoneum. Although the projectile itself does not penetrate this membrane, it is important to remember this possibility, because when such wounds are explored it is most probable that the small holes caused by the bony fragments would be overlooked, and the peritoneum assumed to be inviolate.

5. *Rupture of Hollow Organs by Indirect Violence.*—Cases of this class have been reported by Owen Richards, John Fraser, J. W. Dew, and others. An explanation is difficult to arrive at. There are two forms:—

a. Rupture of the intestine by a bullet without penetration. The first case was that of a man whose recti were divided almost completely by a bullet. The wound was explored and the posterior rectus sheath found intact. As there were no symptoms the abdomen was not opened; the man died. At the post-mortem a careful search failed to show any rupture of the peritoneum. There were three holes in the small intestine which lay immediately under the wound in the abdominal wall, showing the gut had not moved, although more than twenty-four hours had elapsed since the receipt of the injury. Fraser's case was that of a man wounded by a piece of shell in the right iliac fossa, the cæcum being found bruised, and a small hole in the mesenteric border of the ileum. In Dew's case the projectile had cut through all the abdominal wall except the peritoneum, through which the cæcum could be seen. As there were no symptoms the abdomen was not opened, but the man died from a ruptured ileum.

b. Rupture of a viscus out of the track of a perforating bullet. Fraser

has also published a case in which the bullet penetrated the abdomen just below the umbilicus; there were no symptoms at first, but when they arose later on, cœliotomy showed a ruptured bladder. The bladder was apparently out of the direct line of the projectile.

It would seem that these ruptures may be caused in two possible ways: (1) When an object such as the abdomen and its contents, made up of layers of varying toughness, is sharply hit, more friable layers underneath may come away, while the more resisting overlying layers remain intact; (2) This may be termed the 'paper-bag' theory, the intestine being ruptured by a smart blow in a similar way to that in which an inflated paper bag is burst on being hit. I do not know that there is any proof that this happens, but it is rather a seductive theory.

There is another possibility which must not be lost sight of: a man may fall to the ground, or against some object, when he is hit, and the ruptured intestine be due to the blow thus produced, and not to the actual missile which was the indirect cause of the fall.

Comparative Frequency of Wounds in the Different Viscera.—The following table gives some idea of the relative frequency with which different organs in the abdomen are wounded. The total number of cases from which the table was made was 965.

Table 7.—Relative Frequency with which Different Abdominal Organs are Wounded. From a Total of 965 Cases.

Viscus	No. of Wounds	Viscus	No. of Wounds
Stomach	82	Kidney	73
Small gut ..	363	Bladder	45
Colon	252	Pancreas	5
Liver	163		
Spleen	54		

Mechanism of Wound Production after Penetration.—The multiplicity of wounds of the small intestine has raised some doubt as to their method of production, especially in the case of bullets, where widely different types of wound are seen. The question arises whether a bullet pursuing a straight course causes these injuries, or if we must invoke a rotation of the bullet, or a bursting effect. If a bullet is rotating quickly on a transverse axis, it could easily produce complete division of the gut, but if it is rotating quickly enough to produce such injuries, it is hard to see how it could at the same time produce small perforations. Some support is given to the rotation theory by the retention of many bullets, and one knows that their flight is unstable at the end. If the rotation theory is correct, one ought to have some evidence of this rotation at the entrance and exit holes. As a fact, it is impossible to establish any relations between the size of the entrance and exit wounds in the skin and the amount of damage done to the intestine. As to the possibility of a bursting effect, it is impossible, I think, to make any definite statement on the subject. All one can say is that when great vessels are hit by bullets, nothing has ever been seen in the nature of a lesion which suggested

the presence of the so-called hydrostatic phenomena. I am rather inclined to think myself that these different types of wound are caused by the varying state of distention of the small gut. As is well known, one meets with lengths of the small intestine alternately distended with air and collapsed. If the bullet strikes a distended portion it will perforate it, or cut a hole in it. If it strikes a portion which is collapsed, the intestine is so small that the bullet is large enough in diameter to divide both coats.

Diagnosis of Intraperitoneal Damage.—This is determined in three ways: (1) By inspection; (2) By experience; (3) By symptoms.

With all possible care and an extensive experience, and a full appreciation of the numerous fallacies, it is frequently difficult to make sure that the wound is penetrating. If it is difficult when there is an entrance and exit wound, it is still more so when there is only one wound. It may be that shock, hæmorrhage, rigidity, or rapid pulse will be present; in some cases which are received early, there will be no such guides. It may be said that the wound of a hollow viscus has in itself no symptoms if it is not extensive enough to produce shock; it is usually hæmorrhage or peritonitis which gives the danger signal. As there is a distinct relation between the interval since the receipt of the wound and the mortality, it is important to be able to determine the probability of penetration.

1. By Inspection.—Anteroposterior wounds are the easiest to judge. The only point to be remembered is the thickness of the flank muscles. Below the transpyloric plane, a wound with the entrance on one side of the middle line, and an exit exterior to the lateral body line of the same side, is very often non-penetrating; or it may have just opened the peritoneum. Above the transpyloric line, such a wound, owing to the rounded form of the thorax, is almost certain to be penetrating. The bullet which passes in and out between the semilunar lines probably does not open the abdomen, while the wound that passes in and out outside these lines probably does. In the longitudinal direction, a bullet which enters near the costal margin, and emerges above the groin, will most likely traverse the abdomen. Where it is a question of single wounds, there is really no guide except the symptoms, as it is usually impossible to tell the direction of the projectile. Much help is afforded by an *x*-ray apparatus in such cases. One case may be quoted as showing the difficulty of judging where a missile has gone: A man was shot beside the umbilicus. The shape of the wound suggested a bullet. The area was a dangerous one, so it was determined to explore the abdomen. As the wound was in a convenient situation, the exploration incision was made through it. It was then found that the rectus muscle was torn the length of the incision. This was enlarged downwards to the pubes, the muscle being much torn down to the bone, but the sheath and peritoneum were intact. The bullet had passed down behind the pubes. As there were no symptoms, nothing further was done, and the case, after an interval of several days, was sent to the base doing well.

2. By Experience.—This has shown that one has to be very careful in making a negative diagnosis, and it has also shown the wisdom of operation in doubtful cases. Bomb wounds require some notice under this heading. The fragments into which a bomb is broken on explosion are often very small, but

so high is their velocity that they have very great power of penetration. The wounds are often so small and insignificant that it sometimes takes real strength of mind to explore the abdomen, although the symptoms point to the possibility of visceral involvement. The number of these wounds makes individual exploration impossible, and the only way of settling the matter is to explore the abdomen by a well-placed incision, irrespective of the situation of the wounds.

3. By Symptoms.—These may be enumerated as follows: Appearance; pulse; vomiting; hæmorrhage; rigidity; pain; tenderness; subjective sensations; shock.

Appearance.—Usually a man hit in the abdomen looks ill. He is shocked and cold, often in spite of blankets and hot bottles with which he has been surrounded in the ambulance. Sometimes he is apathetic and quiet; sometimes restless—sometimes from pain, sometimes from distress. He may be blanched or of a fair colour, even normal in appearance. Before rapid evacuation was the rule, I was struck by the fallaciously good facial expression of some of these cases, and it was often that one experienced a shock, on taking up such a man's hand, to find it cold and clammy, and the pulse running or even not palpable. Such cases invariably die, and operation only hastens their end.

Pulse.—A rapid pulse, a pulse that does not fall, or a rising pulse, is an indication for operation. A slow pulse is not necessarily a contra-indication unless the wound is in a non-dangerous area such as the liver. I have seen a man with a pulse of 60 with four holes in his small intestine, and four hours after receipt of the injury. A rapid pulse is caused by loss of blood, and later on by peritonitis and sepsis. It does not seem to have any very definite connection with the number of lesions of the intestine. The pulse often falls with rest and infusion, and it happens, more often than not, that a falling pulse is more an indication of the possibility of operation than a contra-indication to operative measures. A rising pulse is an indication for operation.

Table 8.—To Show how the Pulse-rate Affects Prognosis. Total Number 577.

Pulse up to and including	60	70	80	90	100	110	120	130	140 and over
To Base ..	1	7	23	30	108	27	37	7	9
Died ..	1	2	13	18	39	38	88	37	92
Total	2	9	36	48	147	65	125	44	101

From *Table* 8 one can see the general average pulse of a man wounded in the abdomen. A pulse of 100 is very common, and, on the whole, gives a good prognosis. A pulse of 120 seems to be a critical one, for the mortality is here rapidly mounting. Of 145 patients with a pulse over 120, only 16 recovered.

Mention may be made here of unexpected results which some pulse-rates show. A man having a pulse of 160 with a wound in the liver, went to the base

without operation. A pulseless man recovered after his bladder and small intestine had been sutured. A man with a pulse of 60 died from the effects of hæmorrhage, although the bleeding was stopped by operation. A man with a pulse of 90 died of gas gangrene in the abdominal wall. Another with a pulse of 80 died of peritonitis on the third day. One case with a pulse of 160 recovered, the reason for the rapidity being an extraperitoneal hæmatoma of the bladder, which was drained. From these instances it can be seen that, although the pulse is a very good indication, there are many surprises for the surgeon.

Vomiting.—Wounds of the stomach nearly always lead to vomiting, and very often to hæmatemesis; but vomiting is also met with in all kinds of abdominal injury; and beyond the fact that its absence shows that the stomach is most probably not involved, it has no special significance.

Hæmorrhage.—This will be dealt with more fully later on; it is sufficient to say here that with the exception of blanching and a rapid pulse, both of which may be produced by other causes, the classical signs, such as restlessness, blindness, or air hunger, are usually absent. Hæmorrhage gives the ordinary physical signs; but as is well known, these are not very helpful, for to produce them the amount of blood may have to be very great.

Rigidity.—This is a very constant, but varying, symptom when the cases arrive. It is seen (*a*) In low thoracic injuries; (*b*) In wounds of the abdominal wall and contusions of the abdomen; and (*c*) With visceral injuries.

a. The rigidity produced in the abdomen by low thoracic injuries is well known, and it renders diagnosis very difficult, especially in cases where, from a study of the track, the bullet may or may not have entered the abdomen. One such case I well remember, in which a man, hit in the lower right axillary region, presented a universal rigidity of the abdominal wall, accompanied by considerable pain. His condition otherwise was not bad. It was determined to watch him, and he was put to bed and kept quiet for three hours. At the end of that time the rigidity had become board-like. There was considerable increase in his pain, and his pulse-rate was slightly accelerated. An abdominal exploration showed that, after all, the abdomen was uninvolved, and that the only possible injury was a wound of the liver on its extraperitoneal surface. Curiously enough, this man died of tetanus a week later.

I do not know that there is any royal road to diagnosis between a thoracic and abdominal wound; every case must be judged on its merits. Captain Maybury has an idea that superficial abdominal tenderness is rather a feature of thoracic wounds.

b. In the wounds of the abdominal wall the rigidity is apt to be local, and, as a rule, does not give rise to very much confusion. Contusions of the abdomen do present considerable difficulty, and in cases which have recovered without operation, I have seen rigidity, an extremely rapid pulse, and pallor all combined. Wounds of the pelvic floor, even when not penetrating, will produce a reflex hardness of the anterior wall.

c. Injuries both of the solid and hollow viscera are accompanied by rigidity. This rigidity seems to be brought about in three ways: (1) It is a reflex protective measure after the receipt of any wound; (2) It is also brought about by irritation of the peritoneum, either by blood or infection; (3) It is

largely independent of the amount of peritoneal infection, and it occurs in extreme form without any naked-eye appearances of inflammation. Under such conditions it is generally accompanied by very great pain.

Rigidity often occurs when there is blood in the abdomen, the source of which is only a wound of the mesentery or omentum. It is not, as a rule, very marked in these cases, and tends to subside with time, in contradistinction to that due to peritonitis, which is progressive. One occasionally sees a somewhat rigid and tumid condition of the abdomen in cases arriving late; such a condition, according to my experience, is usually only a sign of hæmorrhage which has been arrested, and I always advise the leaving alone of such cases.

Considered clinically: (1) Rigidity may be slight, and this generally or locally; (2) It may be confined to one part, and if this spreads it generally means an intestinal lesion very similar to that seen in appendicitis; (3) Alternating rigidity. During examination the abdomen is sometimes soft and sometimes hard. This is a very puzzling condition, and its indication is not very clear; it is sometimes accompanied by extensive injuries; (4) Apprehensive rigidity, if one may use the term. Here, although the abdomen looks soft and moves on respiration, it at once hardens when the hand approaches to palpate. As a rule it is accompanied by no serious injury; (5) Board-like rigidity is most puzzling when accompanied by a slow pulse. If there is extreme pain, it nearly always means that there is a wound of the intestine; (6) Complete absence of rigidity; this, when accompanied with obvious penetration of the abdomen, is a bad sign, as has been pointed out by Taylor and Muir. Such cases quickly end in death.

It may be here stated that morphia in moderate doses seems to have very little effect on the state of the abdominal wall.

The Spinal Abdomen.—One has to be on one's guard not to be misled by the slightly rigid and tumid abdomen which is met with in cases of spinal injury, and especially when such injuries are accompanied by vomiting. This state of the abdomen is sometimes caused by a distended bladder, but it may be present without it.

Tenderness.—This has very much the same value as the tenderness met with in penetration of the intestine due to disease.

Pain is nearly always present in some form or another; but it varies from almost uncontrollable agony to nothing more than discomfort. There does not seem to be any particular relation between the amount of pain and the amount of injury.

Subjective Sensations and *Shock* are dealt with later (p. 735).

Care of the Patient before Operation.

In Transit to Hospital.—Captain Moore has pointed out that a man wounded in the abdomen is more comfortable if he can be put in such a position that his abdominal muscles are relaxed. He should be covered up, kept as warm as possible, and saved all the jolting that may be, though, from the nature of things, this cannot be done very effectively. He should be given a reasonable dose of morphia—this will relieve his pain and mental anxiety.

Morphia.—It is necessary here to say a word about the administration of morphia. After the first injection has been given, a reasonable time should

elapse before another dose is administered. This warning is necessary, because patients have arrived at the casualty clearing station very profoundly under the influence of the drug. This seems to have been brought about in different ways: (1) By the administration of an unnecessarily large dose to begin with: (2) Failure to allow proper time for this to take effect before repeating the dose; and (3) Not infrequently, to the patient being dosed either by himself or by his companions without the knowledge of the medical officer.

The Withholding of Water.—There is no reason why water should not be given in reasonable amounts; its withholding causes great distress to the patient, who is very likely suffering already from a lack of fluid in his body.

In Hospital.—When a patient arrives at an operating hospital, the question of immediate operation has to be considered. It is better to put the man to bed and watch his condition for a little than to immediately subject him to operation. It is quite true that hæmorrhage is the great danger; but still, my experience has led me to think that on the whole a little rest does more good than harm. The interval is used to improve the man's condition.

First and foremost as a remedial measure is the warming of the patient. This is by far the best treatment of shock that I know, and greatly transcends in importance the ministration of stimulants, of whatever nature, either by the mouth or hypodermically. The radiant electric bath covering the whole body is much the most efficient method of applying heat, and should be used wherever an electric current is available.

Fluid can be introduced into the system by the mouth, by the rectum, subcutaneously, or intravenously; it depends upon the state of the patient and his capabilities of reception. The intravenous method is by far the best and surest if time is an object. The fashionable method of subcutaneous saline is practically valueless in a shocked man, and certainly no better than rectal administration. Pituitrin and eserine are favoured by some people.

The actual moment for performing the operation must be left to the individual judgement of the operator. If the man does not respond at all, the question must be decided whether it is best to operate at once or whether it is worth operating at all. The pulse (see "Pulse-rate Table") will give some help. Frequently even as much as six or eight hours' rest will produce such improvement that an operation is possible where at first the case seemed hopeless.

General Lines of Treatment.—Cumulative experience shows the wisdom of operation as a rule, and it is now mainly a question of excluding a few cases on which it is best not to operate. It can be frankly admitted that this line of treatment involves operating on some patients who would have got well without. It also involves operating on a certain number of cases, where there is bleeding without visceral injury, which also might have recovered without. On the whole, it may be said that a policy of 'look and see' is better than one of 'wait and see.'

It may be useful to enumerate those cases which are best left alone.

1. *Cases in Very Bad Condition.*—There are, of course, many cases which no surgeon would feel himself justified in operating on; but there are many borderline cases, which some surgeons would leave, and others would feel constrained to give the chance of operation to. Here the personal

equation comes in, and whether he operates or not must be left to the surgeon to decide. Here, again, the pulse will be a valuable guide. The bolder surgeon will get the worse operative mortality.

2. *Cases Shot High Up in the Abdomen in the Liver Area.*—Such cases on the whole do very well if left alone, so long as there are no symptoms of hæmorrhage—in fact, hæmorrhage is the only reason for operating on liver cases, or those involving any solid organ. It is, of course, true that a certain number of these succumb to sepsis at the base, but their number is not sufficiently great to warrant early interference on that account.

3. *High Abdomino-thoracic Wounds on the Left Side.*—The type of wound more especially referred to is that which enters somewhere near the mid-line behind, and emerges somewhere towards the posterior part of the axilla about the level of the 6th to the 8th rib. These wounds are sometimes accompanied by symptoms suggesting stomach involvement, but on the whole do not seem to do so badly; and operative interference does not afford very much help, as wounds high up in the cardia or near the œsophagus are almost impossible to close, or, if they can be reached, involve such disturbances as are likely to lead to a fatal result.

4. *Cases Arriving Late.*—I am inclined to put down twenty-four hours as a usual limit within which a primary operation is likely to be successful; hæmorrhage by this time has ceased, and operation is only likely to spread infection if the bowel has been perforated, and to hasten the end. There are some cases in which operation may be thought advisable—namely, those with a fair pulse but with vomiting, the operation being performed with an idea of getting over the 'obstruction' by short-circuiting or an enterostomy. Operations of this class have nearly all been fatal.

The so-called Murphy operation, that of simple suprapubic drainage, is, I believe, an absolutely useless disturbance, and has been abandoned by the French, with whom it was an official proceeding in the early days.

The Incision and Subsequent Treatment.—

1. *Its Site.*—This must be planned rather with a view to dealing with the probable nature of the injury than with any reference to the wounds. With an in-and-out wound we know the course of the projectile, and can form a fair estimate of the organs likely to be involved. With a single wound this is practically impossible, and here an *x*-ray apparatus is invaluable, as it enables us to place the abdominal incision in the best possible situation.

To give an instance of the value of *x* rays: Suppose there is a single entry wound near the middle of the abdomen. Without an *x*-ray examination the only thing is to open the abdomen in the middle line and ascertain the course of the bullet; this involves an exploration of the entire abdomen, and in the end it may be found that the only viscus injured is the colon at its peritoneal reflection. The exploratory procedure will have exposed the whole abdomen to the danger of contamination. On the other hand, an *x*-ray picture would have located the bullet in the loin, and shown at once that a horizontal exploratory wound would have met all the circumstances of the case, and possibly saved a life.

A paramedian incision is the standard method of opening the abdomen, and it should be used in all cases unless there is some distinct indication to the

contrary. It is always better to prolong it than to make lateral right-angle extensions. The length should be 6 to 8 inches; probably the longer is the better, as free access means a very great increase in celerity.

In some anteroposterior wounds towards the lateral line of the body, a rectus-sheath incision has something to recommend it; the colon can be easily reached and the field of operation limited. It is not, however, a good incision to close, and divides many nerves.

In those cases where the missile has perforated the body from near the mid-line to the loin, whether this direction is shown by an entrance or an exit wound or by the aid of a skiagram, the transverse incision, either horizontal or parallel to the upper or lower abdominal limits, is much to be recommended. If more room is required, it can be obtained by cutting the rectus sheath, but leaving the rectus muscle intact. Such an incision allows free access to the hepatic and splenic flexures and the vertical colons, to the kidney, and to the spleen. It allows removal or exploration of the kidney without rolling the patient over—a great advantage, for Marshall has shown that such movement is followed by an alarming drop in the blood-pressure at the close of an abdominal operation. It also allows a systematic examination of the small intestine, if necessary. It is the only incision that allows the ascending and descending colons to be easily and properly repaired, and, in addition, is a convenient situation for an artificial anus. It is not a convenient incision for the stomach, except for that portion situated near the spleen.

A similar incision starting behind, and prolonged forward if necessary, can be used with advantage in exploring lateral wounds of the body in the neighbourhood of the cæcum and sigmoid. A subcostal incision is also good in some liver wounds. Such wounds suture easily and heal kindly. In some cases of wounds in the back of the loin it is better to open the abdomen in the mid-line and make sure that the peritoneum has not been involved. If it has, the wound is closed and the loin opened up, and the necessary steps are taken to deal with the condition found. It is always very important, when there is a possibility of a colon wound, to do everything to prevent contamination of the general abdominal cavity.

2. *Its Closure.*—The method of closure must depend on the condition of the patient. If this is critical, it must be by through-and-through sutures. If there is time, an attempt should be made to close the peritoneum separately; many of these wounds suppurate, and it is impossible to prevent the suppuration extending to the intestines if the peritoneum is unsutured. If the patient's condition allows, the wound can be closed in layers, but in every case there should be at least three through-and-through supporting stitches.

Suppuration in the operation wounds has been a trouble. It may be partly due to defective technique; but in many cases one has to remember that the blood in the abdomen, which must well out when the cavity is opened, is full of micro-organisms. Various methods have been tried to prevent infection, but with no great success. On the whole, however, there seems to have been a good deal of improvement. It is curious that the same difficulty is found on operating on acute appendix abscess, where the peritoneum can readily combat the septic condition in which it is left, while the abdominal wound falls a victim to the bacilli.

3. *Abdominal Drainage.*—Opinions differ about this, and personally I never use it, nor do I believe that it has any points to recommend it. When speaking of abdominal drainage, I mean the ordinary drain to the pelvis or loin. It is quite another thing to tie a small drain to a suture line which one mistrusts, the idea of which is to form a local track in the case of a leak.

4. *Flushing the Abdomen.*—Some surgeons favour this procedure, and it has a good deal to be said for it when the abdomen is full of septic blood. At the same time it is difficult to carry out efficiently without much exposure of the intestines. In small local infections without blood it is not to be recommended. Both saline and eusol have been used; but to heat the latter to the requisite temperature is to destroy its efficiency. The cold produced by ether is sufficient to damn it, even if it could cleanse the abdomen; a small amount used to produce leucocytosis may find favour with some.

5. *Post-operative Treatment.*—I do not know that there is anything particular to be done to the patient more than after any severe operation in ordinary surgical practice. The question of infusion or transfusion will naturally arise, and in some cases may be beneficial. Most people treat their cases in a semi-recumbent position. Personally, I would let the patient choose his own posture. As to the administration of morphia, it is better to give it than withhold it if the patient is restless or in pain. Most interest turns on the condition of the bowels. Castor oil, calomel, and pituitrin, all have their advocates. There can be no doubt that pituitrin is a very fine purgative, especially if injected into the muscles; sometimes it requires to be helped by a glycerin enema. Like all other purgatives, it is dependent for its action on a healthy condition of the musculature of the bowels, and if this is paralyzed either by shock or sepsis, it will fail to act. For my own part I am not particularly anxious about the opening of the bowels, and I am fairly convinced in my own mind that the bowels will not give trouble if the case is going to do well; if not—and it is mostly a question of peritoneal sepsis—no purgative is of any real avail. I think I have seen a good deal of discomfort needlessly inflicted by attempts to make the bowels act.

State of the Alimentary Canal in respect of its Contents.—

1. *Stomach.*—The amount of food in the stomach is directly dependent on the time of the last meal. The escape of contents depends on this, and on the size and situation of the wound. If the wound is a small one, and near the lesser curvature or the cardiac end, there will be little found in the abdomen; if, on the other hand, the wound is large, and near the greater curvature, extravasation may be very considerable. It is only in connection with the stomach that free gas has been seen to escape from the wound or to be present in the abdomen

2. *The Small Intestine.*—The small intestine is usually empty, and it is hard to fix any definite relation between the amount of its contents and the time of the last meal. It is in a very favourable condition, from a surgical point of view, even more so perhaps than after the elaborate preparation which has been recently the rule in civil operative practice. The collapse of the gut is not due to escape of gas, for free gas is not found in the abdomen.

The usual absence of any large amount of intestinal contents seems to be connected with a more rapid passage of food along the tube than is usually

considered normal, or else to a very complete digestion. Otherwise, considering the number of cases treated at various intervals after meals, the presence of contents should be more frequent. It is the absence of contents, more than anything else, that accounts for the little extravasation. Should the intestine be loaded, there is a large escape.

In one case we were able to get the exact time of the last meal. A man had a dinner of bully beef and Clarke's beans at 1 p.m.; he was hit at 6 p.m., and operated on at 10 p.m. All evidence goes to show that after a wound digestion and vermicular movements cease, so that one can assume the state of the intestine at 10 p.m. was the same as that at 6 p.m. The operation showed that the man was wounded three and a half feet from the cæcum, and here the bowel contained much fluid and solid matter, including Clarke's beans, which were extravasated to a large extent. This case was under the care of Captain H. Drummond.

Another interesting observation was made by Captain John Fraser. A party of soldiers was shelled in billets just after the mid-day meal, which consisted of large quantities of tea. There were several cases of abdominal wounds. The amount of fluid in the abdomen in some cases of wounded small gut was remarkable, and in contrast to the usual condition. It looked as if the fluid contents had passed rapidly into the small intestine. The stomachs themselves—to judge by one case, at all events—were still full of food. It is a remarkable fact that these patients all died, and mostly from gas gangrene.

3. *The Large Intestine.*—This is usually loaded, and presents a great contrast to the small intestine in this respect. This fact, no doubt, is due to the sedentary life in the trenches. The loaded state of the bowel may have some relation to the infectivity of the contents. On the other hand, a constipated condition tends to limit the escape of contents.

Effects on the Musculature.—When considering this subject a sharp distinction must be drawn between the appearances seen before and after sepsis has produced its effects on the intestine. It is with the former that we are at present concerned. The subject can be divided into two parts, (*a*) the naked-eye appearances, and (*b*) the state of the nervo-muscular mechanism.

The stomach is often normal, both as regards its size and the thickness of its walls. On the other hand, it is by no means rare to find it dilated. This dilatation is, as a rule, of moderate dimensions, but may be of considerable extent, and occasionally passes into a condition of acute dilatation. This last condition is seen both in peritoneal and retroperitoneal wounds, and with and without spinal injury. Apart from actual dilatation seen in the course of operation, many cases after operation present the clinical symptoms of the condition, which is relieved as a rule by stomach lavage, but sometimes ends fatally. It would seem therefore that it is not uncommon for some paresis of the stomach to occur.

An experiment performed by Captain H. Drummond and myself may be of interest in this connection. A dog was given a weighed meal containing bismuth. A skiagram showed that the organ emptied itself in six hours. The experiment was repeated, with the addition that the animal was anæsthetized for half an hour. There was no delay in the emptying of the organ. Another experiment was performed similar to the last, but in this instance a resection

and suture of intestine was performed. The stomach had not begun to empty itself in six hours.

It might be objected that the vomiting that so often accompanies stomach lesions, and occurs even when there is a large gash in the organ, shows that paralysis is not usual. Against this can be placed the fact that vomiting is a constant symptom in acute dilatation.

The small intestine presents alternate lengths of moderate distention and collapse, and on the whole the calibre of the tube is on the small side of that usually seen in civil practice. Sometimes this condition is exaggerated, and the appearance of the abdominal contents when first seen on opening the belly is comparable, as Fraser has said, to that of a formalin body. Very occasionally a wounded segment of the gut presents a local dilatation both above and below the lesion. It would appear that the intestines are paralyzed after injury for a considerable period. This is supported by the fact that when a case in which the missile has taken a comparatively superficial course, and wounded the gut as it lies against the anterior belly wall, has come late to operation, the wounded intestine is still found in the place where it was hit. The same thing has been noted in those cases where the gut has been ruptured without abdominal penetration, and death has ensued; the wounded intestine has been found lying beneath the wound of the abdominal parietes. I have seen the wounded gut still in the place in which it was hit after thirty-six hours. Sir William Watson Cheyne described a similar case in the South African War, where the gut remained in position after three days.

It is at present impossible to say definitely how long on the average the gut remains paralyzed; the only other observation bearing on this subject is that visible peristalsis has been seen in the jejunum eleven hours after injury. It is possible that a persistence of such a paralytic condition of the gut is the source of trouble after a resection, and two cases apparently of this nature have been reported by Richards and Fraser.

Some experiments seem to show that in animals, after a resection, the upper segment of the intestine remains paretic after the lower one has regained its power, and that the last part of all to become normal is that in the immediate neighbourhood of the resection. It is possible to start a peristaltic wave in the lower segment some time before it can be originated in the upper, and even when a contraction can be brought about, it fails to move, remaining as a stationary constriction of the gut.

WOUNDS OF PARTICULAR ORGANS.*

ŒSOPHAGUS.

Wounds of the œsophagus are very rarely seen, while wounds of the pharynx and trachea are more common. The rarity of wounds of this tube must, I think, be due to the fact that anteroposterior wounds involve the

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* *Note:* *a.* The number of times that injuries of solid organs complicate injuries of other organs (both hollow and solid) is probably understated, though the proportion of such complicating injuries of solid organs to one another is approximately correct.

b. In speaking of the causes of death, no reference has been made to injuries other

spine, and transverse wounds involve the great vessels. Some of the lower thorax wounds which are accompanied by vomiting may be wounds of the œsophagus, but there is no clear proof of this.

One curious case may be quoted where a man was hit in the back about the fourth right interspace. He was treated for a thoracic wound, as there were no localizing symptoms. Two days later he passed per anum the core of a bullet, and the day following, the mantle.

STOMACH.

Frequency.—In 965 operated cases the stomach was perforated 82 times. In 55 instances it was the only hollow viscus damaged. There were a good many other instances in which its wall was bruised or scored.

Situation of the Injury.—This is shown in *Table* 9 :—

Table 9.

Site of Wound	Alone	With other Hollow Viscera
Anterior wall	26	8
Posterior wall	5	1
Anterior and posterior walls ..	14	10
Greater curvature	2	1
Lesser curvature	2	1
Cardia	2	1
Near œsophagus	2	0
Lesser curvature and posterior wall	1	0
Totals	54	22

The number of times both walls have been perforated and other hollow viscera (both small and large gut) wounded, is rather remarkable, when one remembers how innocuous anteroposterior epigastric wounds were supposed to be.

The fact that the posterior wall may be wounded alone, or in conjunction with the posterior surface of the transverse colon, is of importance, as neither of these places is visible unless a special search is made, and I have known such wounds missed at operation.

Associated Wounds of Other Organs.—

Hollow Viscera.—Small gut, 19 ; colon, 13.

The jejunum is the part of the small gut most frequently hit, very often within a short distance of its commencement. These high injuries are especially caused by side-to-side wounds which catch the bowel as it lies high up in the abdomen in front of the kidney. When the projectile pursues a more vertical course, the ileum is also injured, or injured alone.

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than abdominal ; but in many cases the fatal result must be largely put down to injuries other than those of the abdomen.

c. The lesions of hollow organs enumerated in the tables and in the text are perforative lesions. Every single viscus was bruised or had its outer coats injured on many other occasions.

The transverse colon is, more frequently than any other part of the great gut, injured along with the stomach; but parts so far distant as the pelvic colon and cæcum have also been hit. The splenic flexure escapes more often than one would expect. Sometimes, in addition to the transverse, the ascending or descending colon is wounded. Such wounds are caused by projectiles having a highly inclined side-to-side course.

Solid Viscera.—Liver, 15; spleen, 5 (all fatal); pancreas, 3; kidney, 4.

A few examples of complicated injuries may be given :—

Anterior wall—spleen—kidney (Died).
Stomach—pancreas—kidney (Died).
Stomach—liver—kidney (Died).
Anterior and posterior walls—transverse colon—small gut (Died).
Anterior wall—transverse colon—jejunum (Died).
Lesser curvature—descending colon—liver (Died).
Anterior wall—cæcum.
Anterior wall—descending colon (Died).

Nature of the Wounds.—The stomach affords many types of wound, nearly all easily explained by the nature of the projectile and the course it takes. Sometimes the stomach wall is exposed by the carrying away of the anterior abdominal wall. At other times prolapse of the stomach takes place, accompanied by that of the colon, small gut, and spleen.

Bullets passing in an anteroposterior direction make small perforations. Shrapnel balls cause larger perforations, the edges of which are more excoriated than is the case with bullet wounds, and the larger size and rounder form of the ball cause it to bruise the wall before it bursts its way through. Shell and bomb fragments make wounds commensurate with their size and shape. When the axis of the flight of the projectile is more or less parallel to the walls of the stomach, the wounds become larger—sometimes a linear slit, sometimes a linear slit followed by a perforation, to which the name of 'note of exclamation' may be given. The linear type of wound is nearly always on the anterior surface. When the projectile passes in through the epigastrium and out by the axilla, the slits tend to become parallel to the greater curvature. When the missile takes a more vertical course, the wounds are inclined at an angle to the greater curvature, and the anterior wall of the stomach, or its antral portion, may be almost completely divided. Projectiles hitting the greater or lesser curvature in an anteroposterior direction sometimes cause rather extensive V-shaped injuries involving both walls (*Fig.* 420). Bruises or cuts in the peritoneum or muscular coats are not infrequently met with.

The mucous membrane does not pout when the wounds are small; but in the case of linear wounds it becomes extruded just as it does when one incises the stomach wall in doing a gastrojejunostomy.

Bleeding.—Wounds of the stomach are accompanied by very severe hæmorrhage, which may come from the organ itself or from vessels or organs near it. The hæmorrhage as a rule does not come from the actual wall, but from the vessels as they run up and down its surface. The bleeding may take place either into the stomach or into the peritoneal cavity.

Symptoms.—Vomiting is a very constant feature—in fact, the stomach is the only viscus which almost always furnishes this symptom. One is often surprised that vomiting is possible, when the size of the wound in the organ is

considered. There is sometimes an escape of gas from the wound, but no particular diagnostic value is to be attached to the presence or absence of liver dullness. The escape of contents has already been dealt with.

Treatment.—Operation is to be advised in all cases except those where, from the track of the bullet, the wound is most probably situated near the œsophagus, in the fundus, or the upper portion of the cardia. These lesions are almost impossible to repair, but I fancy that I have seen two cases in which recovery followed such a lesion.

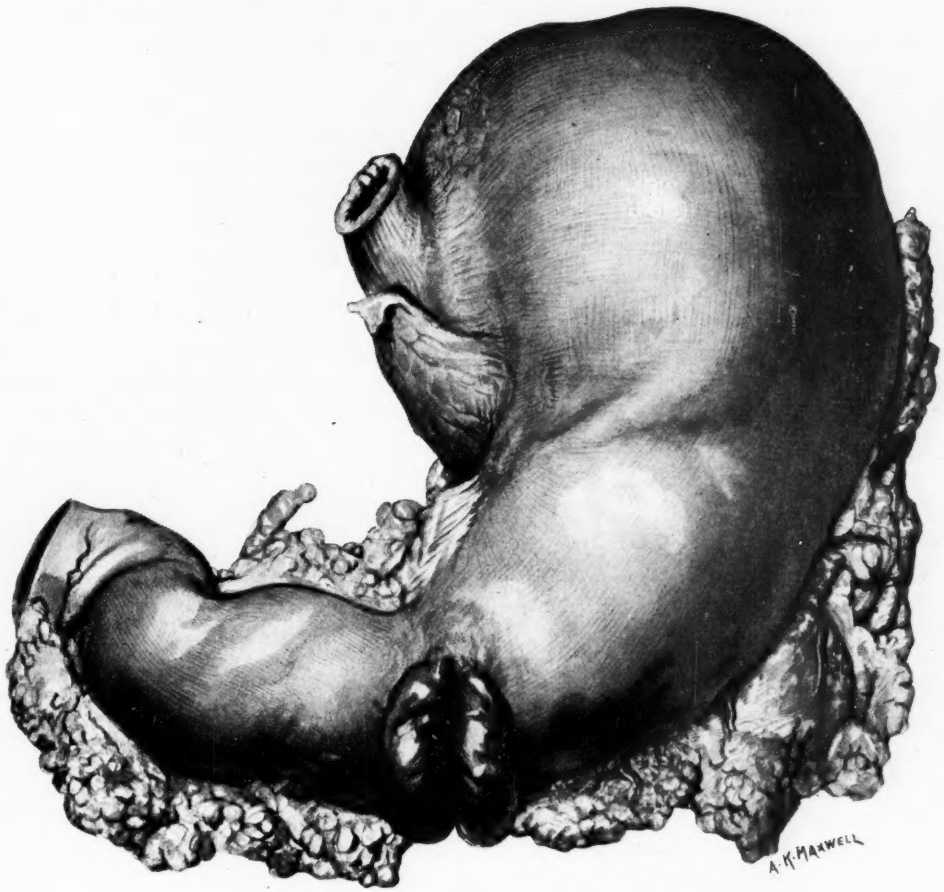

FIG. 420.—Bullet wound of greater curvature of stomach.

The best incision is a paramedian one. As a rule one can tell if the posterior wall is likely to have been involved. If this is the case, or if there is any doubt, the posterior surface must be explored through the gastrocolic omentum in the usual way. The suture of such wounds may be very difficult. Wounds of the lesser curvature involving both coats are also troublesome to suture. There is no need to excise the wounds unless they happen to be very ragged. Gastro-enterostomy may be necessary in cases of wounds dividing the antral portion or the duodenum, or in some cases of narrowing of the stomach. This should only be done in cases of very evident necessity.

Prognosis.—The maximum period of successful suture after receipt of the wound is thirty-six hours, and the prognosis depends largely on the amount of hæmorrhage that has taken place, and on the association of other wounded organs. The amount of peritonitis present does not depend very directly on the length of time between the injury and the operation.

Possibility of Spontaneous Recovery.—This has already been admitted; it only remains to be said that a great many of the injuries could not have resulted in this favourable termination.

Secondary Complications.—A secondary hæmorrhage is not a very uncommon event, and may take place as early as the fifth day; but it is much less frequently seen now than it was formerly.

In the *British Medical Journal* of April 8, 1916, Major T. R. Elliot and Captain Herbert Henry made some important remarks on the "After-history of both Operated and Unoperated Gastric Wounds." They showed that sutured and non-sutured wounds, and contusions, are subject to ulceration, secondary hæmorrhage, and perforation. Secondary hæmorrhage occurred on the sixth, twelfth, and fifteenth day respectively; death occurred on the ninth, twenty-sixth, and twenty-fifth day—the first from hæmorrhage, and the last two from peritonitis. Major Elliot thinks this points to the necessity of careful feeding, and especially to the withholding of extractives. Subdiaphragmatic abscesses have been met with, but are not so common as might be supposed—even in the pre-operative days, according to Sir George Makins.

Mortality and Causes of Death.—In cases uncomplicated with wounds of other hollow viscera, the mortality is 52·7 per cent (in the first 500 cases the mortality was 43·7 per cent). In those complicated with lesions of other hollow organs, the mortality rises to 77·8 per cent. The increased gravity of multiple wounds of different organs is thus well shown; for while the stomach has a mortality of 52·7 per cent, the small intestine of 65·5 per cent, and the great gut of 59·7 per cent, the combination of such injuries shows a mortality of 77·8 per cent.

When the effect on the mortality of an associated wound of a solid organ is considered, the result is not so clear. Thus, in 38 cases, of which 17 recovered and 21 died, we find that there were 5 cases of liver wound among the recoveries, and 5 among the deaths. Among the deaths, there were also 4 cases of injury of the spleen, 1 of the pancreas and liver, 1 of the pancreas and kidney, and 1 of the pancreas. The complication of spleen and pancreas injury would appear to be a grave one.

Out of 29 fatal cases uncomplicated with injuries of hollow organs, the actual cause of death in 25 cases was as follows: shock and hæmorrhage, 15; peritonitis, 5; lung trouble, 2; gas gangrene, 3.

SMALL INTESTINE.

Frequency.—In 965 operated cases, the small gut was found wounded 363 times. In 255 instances it was the only hollow viscus wounded.

Associated Wounds of Other Organs.—Stomach, 19 (5 with colon); colon, 89 (5 with stomach); rectum, 4; bladder, 16; liver, 7 (gall-bladder twice involved); kidney, 7; spleen, 3. It is most probable that the liver

was wounded more often than these figures indicate. The numbers for spleen and kidney are approximately correct.

The sites of the colon wounds were as follows: cæcum, 13; ascending colon, 6; hepatic flexure, 7; transverse colon, 23; splenic flexure, 3; descending colon, 13; pelvic colon, 18.

Nature of the Wounds.—There does not seem to be any great difference in the frequency with which the jejunum and ileum are wounded, though perhaps the figures at my disposal are too small to draw a comparison, as the site of the lesion has not been stated with sufficient frequency. In the case of the duodenum, one may state with accuracy that it was wounded 16 times among 363 small-gut injuries.

The injuries of the ileum would appear to be more serious than those of the jejunum. This is also supported by the fact that cases suitable for suture are more common in the upper than in the lower bowel—a circumstance to be expected when the size of the tube and thickness of the walls of the jejunum are compared with the smallness of the tube and the thinness of the walls in the ileum. The multiplicity of the coils in the latter also favours more extensive injury.

The character of the small-gut wounds varies in some degree with the projectile that caused them, but not to the extent that one might expect. A bullet may inflict as severe an injury as a piece of high-explosive shell. It used to be thought that a patient shot with a bullet had a better chance than one injured by a shell fragment. The present war has proved this to be a mistake. As a matter of fact, the least severe wounds are caused by the small bomb or shell fragments.

Bullet Injuries (*Fig.* 421).—The injury may be complete or incomplete—i.e., it may open the lumen, or it may only score, bruise, or tear the outer coats.

The most common injuries are the perforations made by the bullet striking the intestine at right angles to its long axis. Here there are two perforations, through which the mucous membrane pouts to form a small round rosette. Some holes are so small as hardly to admit the kind of bullet that made them. Through such holes the mucous membrane does not pout. As the flight of the bullet becomes more inclined to the transverse or long axis of the gut, the perforations become slits, but there are still two separate wounds. These wounds gape somewhat, and the mucous membrane overlaps the cut muscular coat so that a considerable mucous surface meets the eye. The general appearance still suggests a rosette, but with one axis longer than the other. The two slits may enlarge until the continuity of the intestine is only maintained by two narrow strands of the wall.

In other cases there is only one wound, involving different portions of the circumference of the intestine; it may reach from near the mesenteric border to near the free margin, or involve the free margin only. In other cases the free margin is slit right back to the mesenteric border, so that only a narrow strip of wall remains; the last piece to be divided is usually the mesenteric portion. Here there is a wide gaping wound with an extensive exposed mucous surface; in extreme cases the gut is completely divided. In another extreme form of injury the intestine is only represented by a long

narrow strip of bowel; its appearance suggests that some animal has gnawed or worried it.

The explanation of the transverse direction of the lesions is to be found in the looped arrangement of the small intestine, whereby the greater part of the tube lies in a vertical direction. As a man is usually shot either from

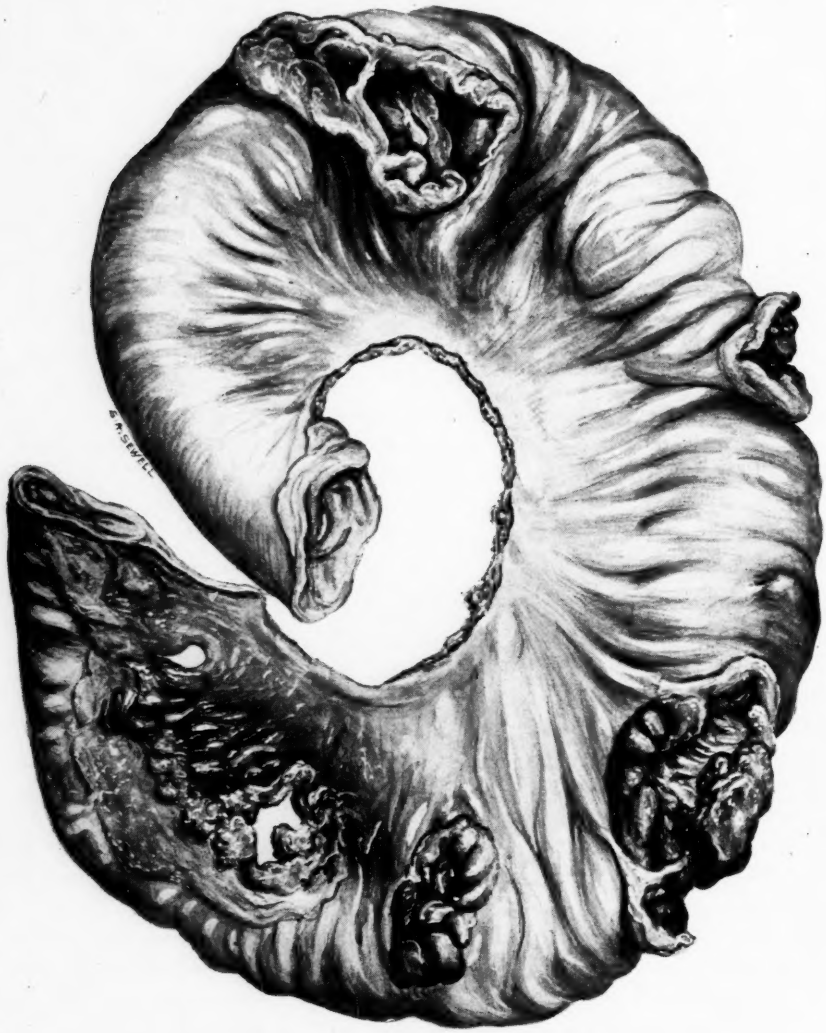

FIG. 421.—Bullet wounds of small intestine.

side to side or from before backwards, the missile will hit the intestine at right angles. If the bullet takes an up-and-down direction, one meets with longitudinal lesions of the gut.

Shell Fragments.—These cause wounds of all varieties, generally commensurate with their size.

Shrapnel Balls.—These cause ragged perforations or tears of moderate size.

Bombs.—Bomb injuries often cause small multiple wounds, which are frequently collected together over a short length of the gut. The mucous membrane very often does not pout, as the hole is so small.

Intimate Nature of the Lesion.—The eversion of the mucous membrane is due to its redundancy, and also apparently, from an examination of microscopic sections, to a retraction of the longitudinal coat (Captain McNee and Captain Dunn). Microscopic examination of the wounded edges shows, further, that the lesion is a very local one; in fact, the appearance is no more remarkable than one would expect if the intestine had been cut with a pair of scissors—it usually consists of a blood infiltration in the neighbourhood of the wound. The mucous coat stains well and distinctly right up to the tear (*Fig.* 422).

Number of Injuries.—In 124 cases the average number of lesions was 4·8: in 40 cases in which resection was performed the average number was 6·2, and in 84 cases treated by suture it was 4·1. Single lesions are the exception. The greatest number of lesions was 17, and the highest number in a case that recovered was 14; this case was treated by suture.

The lesions are usually situated fairly close together, but occasionally they may be scattered over the whole length of the bowel. Sometimes they are met with in two groups; it is in such cases that multiple resections are necessary if the tears are extensive.

The length of bowel involved may be gathered from the following figures, which represent in 25 consecutive cases the amount resected (in inches): 30, 48, 18, 24, 30, 48, 48, 108, 30, 18, 48, 8, 20, 24, 36, 5, 48, 48, 24, 30, 48, 24, 16, 30, 24. In some of these cases, in addition, other lesions were sutured when they lay at some distance from the more severe injury.

Symptoms.—There is nothing more to be added to what has been said under the heading of "Diagnosis of Intraperitoneal Damage" (see p. 695).

Treatment.—A long paramedian incision is the rule, except in those cases which have been dealt with when the site of the incision was discussed.

The actual operative technique in the abdomen is as follows: Any blood present must be got rid of, and the bleeding stopped. As a rule the whole length of the small intestine must be explored, with the possible exception of those cases of side-to-side wounds involving one half of the abdomen where a transverse incision shows that the colon has been involved alone. In such a case, if there is no blood, and the whole length of the missile track can be seen, it may be possible to exclude small-gut injury.

The cæcum or duodenojejunal junction is first picked up and brought out of the wound; then the intestine is inspected, taking care to look at both sides, and replacing the examined part within the abdomen. If a small hole is found, and the gut beyond it for six or eight inches is intact, the hole is sewn up, one suture being as a rule sufficient; if the next lesion that is encountered is a small one, the process may be repeated. If, however, the first lesion is a large one, it is better to cover it up with gauze and a clamp and then proceed with the examination of the whole length; for a big lesion, if quickly followed by another, may necessitate resection, and the amount to be resected can only be determined when the total injuries are known.

When the small intestine has been dealt with, the stomach is explored

if there is any likelihood of its being injured. The colon is dealt with last of all, as it is here that an artificial anus may be very likely necessary. If, however, a transverse incision has been used, it is best to deal with the

FIG 422.—Gunshot wound of small intestine. Microscopic section of intestinal wall, showing eversion of mucous membrane. It will be seen that the damage is of a sharply localized character.

great-gut lesion first, and so limit the possibility of further spreading the infection.

Suture or Resection.—Suture should be practised when possible: small discrete injuries, however numerous, should be sutured; and it is probably best if the injuries are severe, or even complete, provided they are not too near together. It is also better to narrow the bowel than to resect, even if it involves a lateral anastomosis. Resection should be reserved for cases where the bowel is practically destroyed, where there are several severe injuries or complete divisions close together, and where injuries extending into the mesentery, or infarction of vessels, give no choice.

The following figures show the length in inches resected in some successful cases taken in order: **36, 15, 36, 8, 8, 44, 12, 36, 9, 18, 8.**

Double resections in this series have always been fatal, though I know of one successful case.

The results of suture and resection in uncomplicated cases are as follows:—

Table 10.

Operation	To Base	Died
Resection ..	26	87
Suture ..	59	71

The greater fatality of the resection cases depends largely on the initial injury, especially on the loss of blood; but in reading over the cases, one finds many instances of resection where the condition of the patient was at any rate fair, and yet a fatal result followed. It seems as if resection did definitely increase the shock.

Circular versus Lateral Suture.—The old controversy is still unsettled. Results are as follows (*Table* 11), the balance being in favour of lateral anastomosis, but the numbers are too small:—

Table 11.

Operation	To Base	Died
Circular enterorrhaphy	18	69
Lateral anastomosis	8	18

If a lateral suture is used, it would seem best to let the two portions of the bowel overlap well, so as to get the lateral opening in the gut a little distance away from the ends, where mobility is last to return.

Primary Short Circuiting; Enterostomy.—These operations have been done at the primary operation to relieve a dilated upper segment, or as a purely prophylactic measure. I do not think that they are to be recommended, though possibly useful if the upper part of the bowel is distinctly dilated from sepsis. They have, I believe, been abandoned.

Secondary Short Circuit (*Fig.* 423).—This has been done on several occasions, but with little success (1 in this series).

Treatment of a Prolapsed Knuckle.—In the early days there was some difference of opinion as to what was the best treatment for this condition.

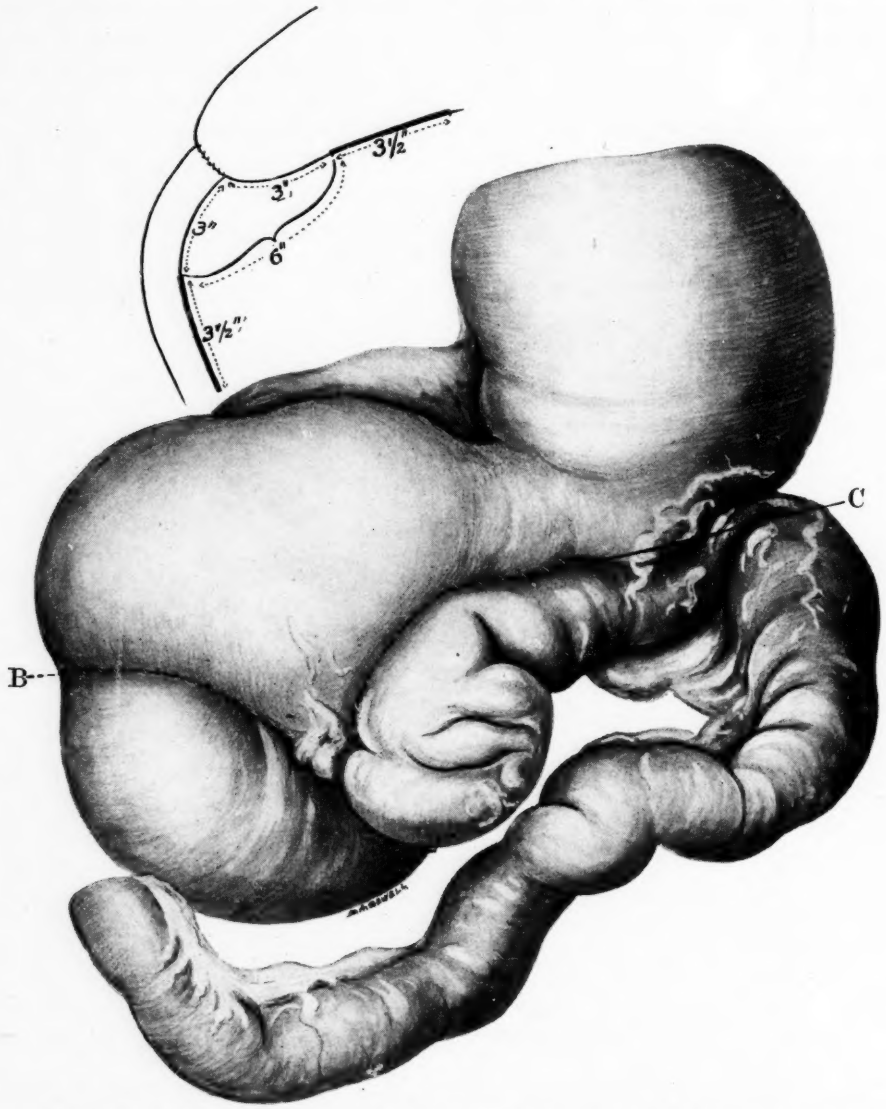

FIG. 423.—Secondary short-circuit of the small intestine. The figure shows post-operative dilatation of the gut extending down over the first suture line to the new anastomosis. B. Primary suture line. C. Secondary suture line.

Nowadays, with the establishment of the operative treatment, most probably the right thing to do is to open the abdomen and deal with the lesions which are found.

Time Factor.—This has been already dealt with, and it only need be

again mentioned that hæmorrhage is a great bugbear and causes early deaths. It may also have a distinct bearing on the later deaths from peritonitis, by spreading infection in the abdomen.

As regards sepsis, to judge from the peritonitis present, it may have made considerable headway in four hours, or it may be practically absent after twenty-six hours.

Mortality and Causes of Death.—

Table 12.

Site of Wound	To Base	Died	Mortality
			per cent
Small gut	87	168	65·9
Small gut and stomach ..	4	10	74·1
Small gut and colon ..	22	63	
Small gut and rectum ..	—	4	
Small gut, stomach, and colon	—	5	

The following figures (*Table* 13) show the causes of death in a consecutive series of resections and sutures respectively (uncomplicated) :—

Table 13.

Cause of Death	Resection	Suture
Peritonitis	14	14
Missed lesion	1	3
Shock and hæmorrhage ..	15	11
Gas gangrene of belly wall ..	5	4
Asthenia	1	1
Paralytic ileus	—	2
Pulmonary embolism ..	—	2
Pneumonia	—	1
Bronchitis	—	2
Gangrene of lung	—	1

The suture line has on very few occasions shown any fault, and where peritonitis has supervened, it must be put down to other causes. Owing to the nature of the contents of the upper bowel, probably greater care should be taken in entering the jejunum than the ileum.

The following figures (*Table* 14) show the average number of lesions in fatal and successful cases respectively :—

Table 14.

Operation	To Base	Died
Resection	4·1	7·1
Suture	3·45	4·27

When the comparative dangers of a wound of the duodenum, jejunum, and ileum are considered, the figures at my disposal are not very adequate,

since the jejunum and ileum have not been distinguished a sufficient number of times. A wound of the duodenum is a fatal injury, as in 11 cases of wound of this viscus, only 2 recovered. As regards the lower part of the small gut, a wound of the jejunum would appear to be the least dangerous.

A wound of the bladder seems to be an extremely serious complication of wounds of the small gut. In the present series there were 16 instances of wounds of this viscus, and all but one died. This is due, partly at any rate, to the fact that when the bladder is injured, the lesion of the small gut is generally very serious, and situated in the closely coiled ileum. On the other hand, half the fatal cases complicated lesions of the small gut that were treated by suture, and presumably, therefore, were not very serious. This would tend to show that there is an inherent danger in a wound of the bladder itself. Very likely the extra time taken to deal with the lesion is a great factor in the result. In addition, there is often a fractured pelvis with these injuries.

There were 3 cases complicated by splenic injury, and 2 of them were fatal. With this exception, the solid organs do not seem to have played a great part in the mortality.

LARGE INTESTINE.

Frequency.—In 965 operated cases, the colon was wounded 252 times. In 155 cases it was the only part of the alimentary tract hit.

Associated Wounds of Other Viscera.—*Table* 15 gives the number of times that the stomach and small gut suffered together with the colon.

Table 15.

Site of Wound	Wounded with Stomach	Wounded with Small Gut	Alone	Total
Cæcum	2	13	16	31
Ascending colon	—	5	36	41
Hepatic flexure	1	7	24	32
Transverse colon	4	22	15	41
Splenic flexure	—	3	18	21
Descending colon	2	9	17	28
Pelvic colon	—	18	23	41
Not stated	4	12	6	22
Totals	13	89	155	257

Note: a. There were several cases in which two parts of the colon were wounded; the highest wound only has been given.

b. There were 5 cases in which the stomach and small gut were both wounded along with the colon. The total colon wounds therefore number 5 less than the grand total given in the table.

The comparatively small number of times that the splenic flexure was injured is somewhat remarkable. It may be that the difficulty of differentiating between transverse and descending colons and splenic flexure may have something to do with this, and that some of the injuries of the two former parts should really have been described as lesions of the latter; the observations were made, however, by a number of operators.

The solid organs do not often seem to be injured at the same time as the colon. The kidney was hit 7 times, the liver 7 (hepatic and transverse colon), and the spleen 7. The bladder was injured 4 times (for 2 cases of associated wounds of the bladder and rectum, see Rectum). The ureter was injured in 2 cases.

Nature of Injuries.—The injuries of the large intestine are really similar to those of the small gut. The differences that are to be noted are due to (1) its larger size, (2) its absence of coils, (3) its absence of mesentery, and (4) its proximity, in some portion of its extent, to bone.

1. The large size of the tube leads to a preponderance of tears or perforations; but instances are met with in which the whole lumen is completely divided, and this happens both in the fixed portion and in that endowed with the mesentery. This complete division is, I think, due to a collapsed condition of the gut, when it may be, as is well known, but little bigger than the small intestine.

2. The absence of coils means that multiple injuries are not common, and when they occur are not so numerous as in the small intestine. The multiple injuries are found at the bends. In one case which may be mentioned, there were six perforations—two in the ascending colon, two in the hepatic flexure, and two in the transverse colon. In another case there were three wounds in the cæcum and ascending colon, and two in the hepatic flexure. In a third case there were five wounds in the pelvic colon.

3. The absence of the mesentery over the great part of the colon means a frequent occurrence of retroperitoneal wounds. These are difficult to find, and are largely responsible for the heavy mortality. The partially covered portion of the small intestine—namely, the duodenum—has likewise a very large mortality.

4. The proximity to bone leads to wounds of the cæcum, the two vertical colons, and the pelvic loop, by spicules of bone; and, as has been pointed out, these injuries are apt to be overlooked, because the perforations in the peritoneum are not conspicuous.

Infarction.—This type of injury is met with in the small intestine, but I think it is rather commoner in the large. The cæcum with the ileum, and the descending and iliac colons have all been found in this state. Interference with the blood-supply also leads apparently to an ulceration of the mucous membrane, which comes on fairly quickly after receipt of the wound. Captain Dunn has collected several cases of this type of injury which he will publish in due course.

Escape of Contents.—The large intestine is often laden, but the condition of the contents renders massive escape less frequent than it would otherwise be; however, taken all in all, escape from the large intestine is more frequent than from the small, especially when the cæcum and ascending colon are involved.

Character of the Lesions in the Different Parts of the Colon.—

Cæcum.—There have been a fair number of cæcal wounds. Most of them have been small in extent, and have lent themselves to suture. In other cases the wounds have been so big as to necessitate an artificial anus. In one case there was bruising of a transposed cæcum. In a good many cases there

was a large retroperitoneal hæmorrhage; and it may be here mentioned that this injury was in one instance accompanied by acute dilatation of the stomach.

Transverse Colon.—All kinds of wounds are met with here, from a simple single lesion to complete division. True anteroposterior wounds are not common, and as a rule the transverse colon is struck obliquely, the bullet passing through the anterior part of the lumen. It has already been stated that such wounds are often accompanied by lesions of the stomach and small intestine.

The posterior surface is sometimes wounded, and this may be overlooked unless it is borne in mind that such an injury is possible, for it is not obvious unless a special search is made. Bleeding from the vessels supplying this portion of the bowel is fairly frequent.

Vertical Colons (Ascending and Descending Colon).—It is convenient to take these two portions together, as they have no mesentery. Both, and especially the descending colon, lie rather further from the lateral line than would appear. The wound may be completely intraperitoneal or extraperitoneal, or both combined. The actual lesions are perforations, slits, tears, or complete divisions. Perforations are most commonly met with in side-to-side wounds, and complete division in anteroposterior wounds. All varieties may be complicated with small-gut injuries. At the base Makins noticed that wounds of the ascending colon were more common than other colon wounds; and he attributed the frequency of the complicated descending colon wound, compared with that of the ascending, to the fact that the small gut overlies it. This explanation seems to a certain degree just. Out of 41 wounds of the ascending colon, only 5 were complicated by small-gut lesions; whereas 28 wounds of the descending colon had associated small-gut injuries in 9 instances. On the other hand, wounds of the ascending colon are more frequent than those of the descending—41 to 28. The comparative rarity of descending-colon wounds may be due to the fact that the descending colon lies so deep, that any bullet passing from side to side and involving it and the small intestine would traverse a coronal plane situated so far back in the body as to involve the spine and great vessels. Of course an anteroposterior wound would involve both the small and large intestine here, but these are not so common as the side wounds.

The intraperitoneal wounds of the vertical colons are fairly easy to find and to deal with if a suitable incision is used. The extraperitoneal are very difficult, and most probably are more often missed than any other. In the first place the extraperitoneal wound, which may be small and valvular, is difficult to find because it lies in a mass of areolar tissue; and the difficulty will be greatly increased when this tissue is infiltrated with blood, as it so often is. The great danger is that of an infection of the areolar tissue. To this class of case Fraser has given the apt term 'colon septicæmia.' I have seen it prove fatal within twelve hours, and that with an open wound.

Hepatic Flexure.—Next to the transverse colon the hepatic flexure is the easiest of all to deal with, as it lies fairly superficially. Its form leads to multiple injuries.

Splenic Flexure.—This, from its position, is the hardest of all the large

intestines to deal with, and even with the best-placed incision it is difficult to properly examine without mobilization. One cannot help thinking that the presence of the splenic flexure has something to do with the mortality which has been shown to exist in wounds involving the left hypochondrium (see *Fig.* 417).

Pelvic Colon.—This portion of the large intestine is, anatomically, more like the small intestine than any other part of the colon, and the lesions are somewhat similar. There are slits, perforations, or complete divisions; and it is, next to the transverse colon, most often complicated with multiple small-gut and bladder injuries. Fracture of the pelvis, so often associated, increases the gravity of the case. I have been struck with the great variations in position, as shown by the different situations of the wounds of the gut in different cases in which the bullet has taken a similar direction.

Symptoms.—The symptoms of intraperitoneal wounds of the large gut are similar to those of the small intestine. A great difference lies in the behaviour of the extraperitoneal wounds, where all grades of infection are met with. Sometimes we have cases of acute sepsis, with or without gas formation, which are fatal in a few hours. Such cases are often past help when they arrive. They are cold, blanched, and clammy, and the pulse is running; in fact, their appearance often suggests acute hæmorrhage. The dangerous sepsis—shown by the high mortality—of the colon anus, when formed in the vertical colons, has led some operators always to make an attempt to close the wound. Unfortunately the damage is already done when the case has come under treatment. In other cases the symptoms are less acute, or are not seen when the case has arrived. Some with a small single loin wound, arriving late, and left, may do well at first; then the usual signs of intoxication and local tenderness appear. In these an incision opening up the wound causes an amelioration. A certain number of cases appear to be due, not to colon infection, but to infected material carried in with the projectile.

Treatment.—In spite of the fact that some unoperated colon cases did arrive at the base and recover, I do not think there are any surgeons who have had experience in operating who would advise abstention on this ground except in cases which arrive late.

Incision.—It may still be necessary to use a paramedian incision for a general exploration of the abdomen, for the exclusion of, or for dealing with, other injuries. The transverse and pelvic colons are best dealt with from such an incision, as these lesions are commonly associated with those of the small gut. It may be necessary in certain cases to supplement this median incision with one towards the side of the body.

When the projectile has traversed only one side of the body, the horizontal loin incision is by far the best; here again the value of an *x*-ray examination in cases of single entry wounds is to be insisted on. The rectus-sheath incision may be preferred by some for exploration of the hepatic and splenic flexures; but the association of kidney injuries with these wounds makes a horizontal incision more expedient, as the kidney can be dealt with in the posterior extremity of the wound, whereas an attempt to remove the kidney through the anterior incision is not very convenient or desirable.

Open wounds involving the loin, and possibly involving the colon, may be dealt with by local enlargement; but in the absence of *x* rays, a median incision to exclude other injuries is most probably the best.

Method of Dealing with the Lesions.—This is largely determined by three factors: (*a*) The size of the tear; (*b*) The situation of the tear; and (*c*) The state of the patient, in whom other injuries may have been dealt with.

Cæcum and ascending colon: here it is better to suture if possible, and provide adequate drainage if there is any possibility of an extraperitoneal wound, or if there is any hæmatoma. In wounds of the extraperitoneal part which have only been found after mobilization of the colon, even if suture is possible, it is advisable to shut off the general peritoneal cavity by a line of sutures joining the anterior surface of the bowel to the lateral abdominal wall.

Transverse colon: the transverse colon is the most easily dealt with of all the colon lesions. When the wound is large, the question is really one of whether suture or an artificial anus is the quicker method of dealing with the case; for here probably other lesions have been dealt with, and the condition of the patient is not likely to be very good.

Vertical colons: small lesions are easily closed if intraperitoneal. Wounds involving the extraperitoneal portions of the gut are dangerous, and, even if they are closed by suture, adequate external drainage must be provided. No doubt suture is the ideal method, but it is often very difficult, and in some cases impossible, owing to the loss of substance. Here the only plan is to make an artificial anus. In the retrocolic hæmatomata so often met with, it is often impossible to exclude colon injuries; these therefore must be freely drained.

Hepatic flexure: the same rules apply here as to the transverse colon, the only point being that mobilization of the flexure may be necessary to get at the lesion.

Splenic flexure: this is the hardest of all to manage satisfactorily, both on account of the difficulty in reaching it, and of the mobilisation necessary to find the hole. An artificial anus is often necessary.

Pelvic colon: this is easily dealt with in its upper portion. Care must be taken to exclude wounds on the border of the gut uncovered with mesentery. In one case a minute fragment of bomb had entered the mesentery, which was here loaded with fat, at a little distance from the bowel, and had penetrated into the bowel at the mesenteric attachment. The Trendelenburg position greatly facilitates treatment of low-lying injuries.

Table 16.

Site of Lesion	Sutured	Artificial Anus
Cæcum	13	3
Ascending colon	25	11
Hepatic flexure	16	8
Transverse colon	13	2
Splenic flexure	10	8
Descending colon	9	8
Pelvic colon	16	7
Not stated	—	6

The preceding table of uncomplicated colon injuries (*Table* 16) shows the site of the lesion and the treatment.

An interesting fact shown in the table is the small number of artificial ani that it was found necessary to establish at the site of a lesion in the transverse colon.

Proximal Colostomy.—I imagined when starting work that proximal colostomies would have a much wider application than I have found to be the case. They are, of course, useful in limiting the amount of septic absorption in cases of wounds of the vertical colons; but, as has been pointed out, this tissue is already infected at the time the cases come under treatment. One does not feel inclined to make an extra opening in the bowel, often at the end of a long operation. Proximal colostomy to be of any use must be complete, and it probably finds its best application in those cases of loin wounds on the left side in which sepsis develops late, and in rectal injuries. A cæcostomy is a perfectly useless procedure. Of 10 proximal colostomies, 5 were for rectal wounds and 5 for wounds below the transverse colon.

Mortality and Causes of Death.—The mortality of colon wounds, uncomplicated with other lesions of the alimentary tube, is 58·7 per cent; it may be compared with that of the small intestine, which is 65·9 per cent. The colon mortality is greatly raised by that of the colon anus, for whereas suture of the colon has a mortality only just over 50 per cent, that of colon anus is 73·5 per cent. This is greatly due to sepsis of the retroperitoneal tissue, which is often very acute, and fatal in a few hours—the colon septicæmia of Fraser.

No definite comparison can be made between the different parts of the colon, as the figures are not large enough. *Table* 17 shows such figures as are available (suture and anus).

Table 17.

Site of Lesion	To Base	Died
Cæcum	8	7
Ascending colon	14	16
Hepatic flexure	8	11
Transverse colon	5	10
Splenic flexure	4	7
Descending colon	8	6
Pelvic colon	8	10

It is interesting to compare the above figures with those given by Makins in the pre-operative days:—

Table 18.

Site	Pre-Operative Period (*Base*)	Operative Period (*Front*)
	per cent	per cent
Small intestine	86	65·9
Great intestine	38·7	58·7

Table 18 clearly indicates that in the pre-operative period a man with a colon wound had the better chance, and this advantage still continues, though the margin is narrower. The question of the disparity in numbers of wounds of the ascending and descending colons that arrived at the base in old days has been dealt with; and it need only be said now that the smallness of the number of wounds of the transverse colon that got to the sea was, partly at any rate, due to the frequency with which injuries of this part are complicated with stomach and small-gut wounds (see Table of Colon Injuries). The position of the vertical colons would favour their lesions becoming sealed off from the general peritoneal cavity, and one still sees instances of this.

RECTUM.

Frequency.—In 965 operated cases the rectum was wounded 21 times.
Associated Injuries.—

Table 19.—A Table of Rectal Injuries.

Viscera Wounded	To Base	Died	Remarks
Rectum alone ..	7	10	3 were intraperitoneal
Rectum and small gut	—	4	All intraperitoneal; all sutured

The bladder was wounded on 2 occasions.
A proximal colostomy was performed 9 times, with 5 deaths.

Character of the Lesions.—Wounds of the rectum can be roughly divided into two classes: (1) Those that may be said to complicate wounds of the buttocks, the ischial fossæ, or the perineum; (2) Those caused by missiles that traverse the pelvic portion of the abdomen. Both are likely to be accompanied by fractures of the pelvic bones, spicules of which may wound the gut.

1. The missile may be a bullet or a small or large shell fragment. In the last case, especially, the external damage may be very great, and a large portion of the gluteal region torn away; the anus and lower portion of the rectum may be completely avulsed, or the lumen opened on one side only. If the projectile is small, the sphincter may be left intact, and the lumen of the tube perforated above that muscle. The peritoneum may or may not be opened. The danger most to be feared is septic absorption; but on the whole, extensive wounds of the buttocks do not do so badly at the front, for they are widely open by the nature of the injury. On the other hand, there is very considerable danger of gas gangrene in the gluteus maximus.

Wounds involving the sacrum, although not opening the gut, have proved very fatal from septic infection of the presacral areolar tissue.

2. The partially covered rectum may be wounded extraperitoneally, or intraperitoneally, or both. Often there are also accompanying wounds of the bladder and small intestine. Missiles that cause such injuries take a side-to-side, anteroposterior, or semi-vertical direction. If side-to-side, the

entrance and exit wounds lie on the posterior aspect of the buttocks, and whether the missile catches the extraperitoneal or intraperitoneal surface, or both, depends on the plane traversed, and the obliquity of this plane to the coronal plane of the body.

The side-to-side wounds are very deceptive, leading one to think, from the posterior situation, that they have missed the bowel.

Treatment.—The two classes of cases require separate consideration.

1. The treatment of wounds not involving the peritoneum follows ordinary lines, and consists of providing drainage by laying open the track and in some way dividing the sphincter (Makins). If the peritoneum has been opened, something may be done by shutting off the abdominal cavity by sutures. The question of colostomy must be considered, and its expediency must be determined by the difficulty or otherwise of keeping the patient clean and comfortable. It will be mostly called for in those cases in which the whole lower segment of the bowel has been carried away and the torn bowel is lying patent in the pelvis. In such cases the lumen may be closed by sutures or a purse-string ligature, which device will at all events tend to limit contamination of the pelvis while adhesions are forming. If a colostomy is necessary, transverse colostomy is the operation of choice, because of the ease of cleansing the opening, of the fitting of a belt which will then lie on the natural line of the waist, and of subsequent closure if this is desirable.

2. There will not be, as a rule, much doubt that an exploratory cœliotomy is the correct procedure; but if any doubt exists, it will be well to err on the side of operation; I refer more particularly to the side-to-side and semi-vertical wounds. If the peritoneal surface has escaped, the abdomen can be closed and the wound opened up from the bowel. Antero-posterior wounds can often be sutured, though from their depth in the pelvis, great difficulty may be experienced. A drain down to the lesion is a wise precaution in all cases, and the question of a transverse colostomy must be determined by the probability or the reverse of the suture holding. The most difficult cases of all are those which involve the rectum at the very bottom of Douglas's pouch, and here a reliable suture is often practically impossible. It has been suggested that it might be good treatment to introduce a tube through the anus up to the side of the lesion, and to cut off the bottom of Douglas's pouch by suturing the peritoneum over it.

When the bladder is wounded in a corresponding position, it is most probably best, as was done by Captain Drummond in one case, to open the bladder and suture the wound from the inside. A suprapubic cystostomy and a simultaneous colostomy are to be avoided if possible.

LIVER.

Frequency.—In 965 abdominal operations the liver was wounded 163 times, and 148 of these were uncomplicated. To these must be added 23 cases in which no operation was done, but in which the liver was almost certainly wounded.

Associated Wounds of Other Organs.—These are shown in *Table* 20. It is probable that the liver was wounded in association with other organs

rather more frequently than the table shows. A liver wound is often a minor complication of a much more grave lesion, and in the pressure of work it is natural that only the more serious injury should have fixed itself in the operator's mind. But when allowance has been made for this, the small number of associated injuries is somewhat remarkable.

Table 20.—The Number of Times Different Organs were Injured in Conjunction with the Liver.

Viscus injured with Liver	To Base	Died	Result not t Known
Stomach	5	6	4
,, and small gut ..	—	1	—
,, small gut, and colon	—	2	—
,, and colon	—	1	—
Small gut	—	1	—
,, ,, and colon ..	—	4	—
Colon	2	5	—
Kidney	3	9	2
Pancreas	—	2	—

Nature of Injuries.—A good many cases of rupture by horse kicks have been seen (though not included in this series); but most of the wounds are caused by projectiles, and aggravated by fractured ribs driven in by the missile. The wounds are of all types, from a simple perforation, or an avulsion of fragments, especially of the anterior edge, to an almost complete disruption.

The wounds are usually commensurate with the size of the projectile: thus, bullets, and small shell and bomb fragments, make perforations or scores; larger shell fragments cause more ragged wounds. The friable nature of the liver, as would be supposed, lends itself to tearing and fragmentation; thus, there may be radiating fissures from a central hole, crater-like exits, or pieces nearly or completely torn off. In some cases a bullet produces the most extensive destruction; this is said to accompany short-range wounds, but as before stated, I am not convinced of it. The track or torn surface is at first ragged and bloody; seen after twelve or twenty-four hours it becomes a dirty yellow-brown; and later it may be a vivid yellow colour due to bilious staining. The injury, to judge from microscopic sections, is usually limited to the vicinity of the wound; and in those cases where destruction of cells is found at some distance from the wound, it is most probably due to an infarction phenomenon (Captain J. S. Shaw). At any rate, these infarcted areas are by no means uncommon.

Hæmorrhage varies; it is not altogether commensurate with the size of the injury, and its amount largely depends on whether a big vein has been opened or not: if not, bleeding usually ceases spontaneously in from six to ten hours. The gall-bladder, and the common and cystic ducts have all been wounded, but the larger bile-passages do not seem to be so often wounded as one might expect. Sometimes in the abdomino-thoracic wounds both blood and bile escape into the pleura, without any special detriment to the patient.

Symptoms.—The symptoms are often slight, and one has no doubt in deciding that the right course is the 'expectant' one. Sometimes the symptoms seem surprisingly severe, and I can recall two cases of tangential wounds of the liver which could not have involved the liver deeply, and in which there was no sign of blood in the abdomen, both of which were extremely shocked, one ending fatally; unfortunately there was no post-mortem. In two other unoperated cases, men with pulses of 160 recovered.

There are the usual signs of abdominal injury, the main ones being those of hæmorrhage, which manifests itself in the usual way.

Jaundice.—Jaundice of a slight and evanescent character, accompanied by bile in the urine in some cases, is seen in the early stages; it is of no great importance, and usually passes off; its cause is not known. The septic form of jaundice which is seen at the base in a considerable number of cases, and which not infrequently ends fatally, is also seen at the front within three or four days of the receipt of the wound. There has also been one case of severe biliary peritonitis which ended fatally thirty-six hours after receipt of the wound; there was much bile in the peritoneum, and no other injury to account for the peritonitis. Of course it is impossible to deny that infection may have been carried in with the projectile. I quote this case because there is considerable difference of opinion as to whether bile can cause peritonitis. In the pleura, apparently, it is often quite innocuous.

For the late facts of liver wounds I cannot do better than refer the reader to Sir George Makins' paper on this subject which appeared in the BRITISH JOURNAL OF SURGERY, No. 12, Vol. III, 1916.

Mortality and Causes of Death.—

Table 21.

TREATMENT	TO BASE	DIED	NOT KNOWN
Operation (complicated) ..	14	26	4
„ (uncomplicated)..	72	32	—
No operation (no indication)	15	—	—

The following list, which shows the clinical cause of death in a series of consecutive cases: jaundice and sepsis, 1; shock and hæmorrhage, 9; 'biliary' peritonitis, 1; lung trouble, 4; gas gangrene, 1.

In uncomplicated wounds, the mortality has a distinct relation with the amount of injury, both because of the quantity of blood lost and on account of the amount of injured substance. No connection has been traced between the direction of the projectile and the fatality, but Makins says that side-to-side lesions were commoner at the base. Injuries of the big bile-passages do not seem to increase the gravity to any appreciable extent.

Treatment.—Some cases require no operation, as there are obviously no other organs wounded and the patients' condition is good. Many cases are operated on solely because of the possibility of injury to other organs. If

such injuries could be excluded, I am inclined to think that the best results would be obtained by non-interference.

The incision for an obvious liver wound is either an '*f*'-shaped rectus incision, or a subcostal one. A recent French work on surgery recommends an incision parallel to the costal margin, passing through the costal cartilages; access to the dome of the liver is said to be greatly facilitated by this method. The actual treatment of the wound when found consists in leaving it alone, packing it, or suturing. The latter is not very satisfactory. The big bile-passages can be dealt with on ordinary lines by suture and drainage.

PANCREAS.

Frequency.—In 965 operated cases the pancreas was wounded 5 times. Very few of such injuries have been noted. Possibly many are missed, and diagnosed as retroperitoneal hæmatoma. In addition, many may be rapidly fatal; the association of the gland with the big vessels need hardly be mentioned.

Associated Injuries.—The organ was found wounded 3 times with other viscera—namely, stomach, stomach and liver, and stomach and kidney. All three were fatal. It was wounded alone on 2 occasions, one of which went to the base without symptoms.

Symptoms.—There are no distinctive symptoms; the lesions are found at exploration, and are often accompanied by fat necrosis.

Prognosis.—One case was sent to the base in which the pancreas was obviously perforated by a bullet; the other cases were fatal.

Makins has published some cases of wounds of this organ which he has seen at the base. He says that they were discovered during the performance of operations for intestinal injuries, and that the typical results of the escape of the pancreatic juice have been observed. They have usually proved fatal. He mentions one interesting case in which an abscess formed and was opened, in which the patient eventually recovered and was discharged to England. This man walked six miles after his wound. He had been detained at a casualty clearing station on suspicion of an injury to the alimentary tract.

SPLEEN.

Frequency.—In 965 abdominal operations the spleen was found wounded 54 times. In 32 instances it was the only organ damaged.

Associated Injuries.—

Table 22.—Table Showing the Complicating Injuries.

Other Viscera Wounded	To Base	Died
Stomach	—	4
Stomach and colon ..	—	1
Small gut	—	
Small gut and colon ..	—	
Small gut and kidney ..	1	—
Colon..	—	3
Colon and kidney ..	—	2
Kidney	7	2

Nature of Injuries.—These consist of perforations, tears, slits, avulsion of upper and lower poles, and complete disruption (*Fig.* 424). The injury is often aggravated by broken ribs. Rupture through an intact diaphragm has been described. (See Rupture of Solid Organs by Indirect Violence of a Passing Projectile, p. 693). There was also a curious case in which a wound was produced by a piece of hard clay (Fraser).

Fig. 424.
Lacerated bullet wound of spleen.

Symptoms.—The symptoms are mainly those of hæmorrhage, and the diagnosis is made on these and on the position of the wound. Very often the organ is only found wounded in the course of an exploratory operation. There is nothing special about the hæmorrhage, and the damming up of blood in the left loin which has been said to be a feature of this injury in civil practice has not been conspicuous in the present campaign. The amount of hæmorrhage varies very much, and depends mainly upon whether the vessels are injured. Unless this is the case, the hæmorrhage has usually ceased when the abdomen is opened.

Treatment.—In uncomplicated wounds, a subcostal incision, or a rectus-sheath incision with a transverse extension, is the most suitable; but unfortunately a diagnosis of splenic injury alone can seldom be arrived at. The kidney is very likely to be wounded, and has been removed with the spleen in several cases. If the hæmorrhage has ceased, the organ is best left alone. Suturing or packing will control the hæmorrhage if this is going on. As a matter of fact, sutured holes are apt to bleed almost as much as a raw surface, unless the hæmorrhage is fairly free. Excision should only be resorted to if the organ is totally disrupted or the vessels are torn.

One point has to be borne in mind in operating on these cases, especially if associated with wounds of the kidney vessels. The hæmorrhage, which very likely has been controlled or diminished by the clotting, is likely to re-start in an alarming manner directly the clot is disturbed. It is therefore absolutely necessary to have everything ready for the arrest of hæmorrhage.

The following table shows the treatment adopted:—

Table 23.

Association with other wounds	Packed, sutured or left alone		Excised	
	To Base	Died	To Base	Died
With other organs ..	5	9	3	5
Spleen alone wounded	12	4	4	12
Totals ..	17	13	7	17

There were 5 cases in which the spleen and kidney were both excised; 2 of these were fatal. The other 2 fatal cases of excision in complicated wounds were instances of wounds of stomach and spleen, and colon and spleen, respectively.

Mortality and Causes of Death.—Shock and hæmorrhage are the main causes of death. One curious case may be quoted, that of a simple perforation of the spleen, where death occurred suddenly without cause on the fifth day. The mortality in uncomplicated cases was 50 per cent, in complicated cases 63·6 per cent.

KIDNEY.

Frequency.—This organ was wounded 73 times in 965 abdominal injuries. It was the only viscus wounded in 34 instances.

Associated Injuries.—The following table shows the number of times each complicating organ was hit.

Table 24.—Kidney Wounds Complicated with Wounds of Other Organs.

Other Viscera Wounded	To Base	Died	Not Stated
Stomach	—	1	3
Small gut ..	4	3	—
Colon	3	4	—
Pancreas	—	1	—
Liver	3	9	2
Spleen	8	4	—

Nature of Lesions.—In two cases both kidneys were hit by the same missile. Both were fatal; one had paraplegia. The nature of the projectile has no particular effect on the injury. As is the case with other solid organs, the kidney is liable to extensive rupture. The actual lesions may be perforations, scores, furrows, avulsion of poles, and hemisection. Sometimes the kidney is found lying loose, the pedicle having been ruptured; sometimes the pelvis is alone perforated; at other times the vessels are completely divided, the ureter remaining intact. The amount of hæmorrhage depends upon whether a vessel has been injured or not; there is very often a considerable perinephric hæmatoma. In contradistinction to civil injuries, intraperitoneal hæmorrhage is very frequent.

Symptoms.—The shock is not as a rule very great, and depends largely on the amount of blood lost; this, perhaps, is peculiar, when one remembers the effect produced by the kidney blow in boxing. On the other hand, one sees cases of kidney injury which recover without operation, in which the pulse may be as high as 140 and the shock extreme. The dullness due to free fluid in the abdomen is more common than in civil injuries, and manifests itself in the right or left side according to the organ injured.

Hæmaturia.—This is usually present, but it may not occur at once. The absence of this sign is due either to suppression, or to the presence of clots or pieces of kidney in the water. Profuse hæmorrhage into the bladder is not common in the early stages. Hæmaturia usually clears up in a few days, but may persist.

Extravasation of Urine.—This is not usually marked, and is most probably limited to those cases in which the pelvis is involved apart from the body of the organ.

Gas Infection.—This has occurred in the perinephric hæmatoma in a certain number of cases.

Excretion of Urine.—The escape of urine through the loin wound is often delayed. This may be due, like the absence of hæmaturia, to suppression, or blocking of the duct. In two cases of double wound no urine was passed into the bladder, though it is doubtful whether there was not some from the loin wounds. Anyhow, the double wound seriously interfered with this function. It is possible, therefore, that if only one kidney is wounded, it ceases secreting.

I asked Lieutenant Sampson, who had a rather extensive experience with these injuries, to measure the amount of urine after the excision of one kidney; the amount if anything was diminished, being somewhere about 25 ounces in the day. The patients were not thirsty, and did not demand water; but if they were put on a forced hydropathy, the remaining kidney at once responded, and passed up to 80 or 90 ounces.

Makins mentions a case in which nephrectomy, performed for late persistent hæmaturia and dysuria, where the daily amount of urine was about 90 ounces, was followed for three days by the daily passage of 7 pints of urine. The quantity decreased until normal was reached on the seventh day.

In the British Journal of Surgery, Vol. IV, No. 15, Captain Bashford has described the changes met with in wounded kidneys.

Secondary Complications.—A secondary hæmorrhage is a fairly frequent late complication, and apparently occurs most frequently during the second and third week after injury. The urine is generally contaminated. Sometimes the secondary hæmorrhage may start afresh, or it may manifest itself as an exacerbation of a persistent primary hæmorrhage. Unlike primary hæmorrhage, it is often accompanied with clotting of the blood in the bladder (Makins, British Journal of Surgery, Vol. III, No. 12).

Treatment.—

The method of treatment adopted in the cases enumerated under 'kidney explored' (*Table* 25) was packing, suture, or nothing, the actual procedure depending on whether the organ was bleeding or not. A loin drain was used in many cases. In a large number of instances it is probable that

the cases would have recovered without operation, which had to be undertaken to exclude other injury. Nephrectomy should be reserved for those cases in which the vessels are torn or the organ is completely shattered. If the kidney is probably the only organ wounded, or if the missile track only crosses one side of the abdomen in a horizontal direction, the transverse incision is the best.

Table 25.—TABLE OF OPERATIONS.

OPERATION	TO BASE	DIED
Kidney explored*	25	7
Nephrectomy (uncomplicated) ..	2	3
,, (spleen wounded) ..	3	0
,, (liver wounded) ..	1	1
,, (bladder wounded)	—	1
,, (colon wounded)..	0	1
,, and splenectomy ..	3	0
,, ,, (colon wounded)	0	2

* In these cases the kidney was considered the principal wound, and so the operation is entered under this head; the kidney was found wounded in many other cases in the course of an abdominal exploration. Among the cases that went to the base were 1 case of wounded liver and 2 cases of splenic injury. Among the fatal cases were 2 cases of liver wound and 1 of splenic wound.

As was stated in speaking of splenic injuries, the hæmorrhage from wounded kidney vessels is very liable to re-start with alarming rapidity directly the clots are disturbed; and it is rather interesting here to mention that the number of kidney wounds treated at an advanced operating centre seems to be larger than in the casualty clearing station. This is most probably due to the fact that the cases arriving earlier have not suffered so much from hæmorrhage.

Mortality and Causes of Death.—In 34 uncomplicated cases there were 6 deaths. Shock and hæmorrhage are by far the most common causes at the front. Associated wounds of the liver and kidney seem to constitute a very dangerous combination. At the base, secondary hæmorrhage and sepsis play the chief part in the fatal result.

URETER.

The ureter is not very frequently injured, and the cases that we have had have done well. The injury was found in the course of an exploratory cœliotomy. Suture or drainage formed the methods of treatment.

BLADDER.

Frequency.—This organ was perforated 45 times in 965 operated cases. In 25 instances it was the only organ injured.

Associated Injuries.—The small intestine is the organ most frequently wounded in association. It is rather remarkable how seldom the pelvic colon or rectum is perforated at the same time. The pelvis is fractured in a large proportion of cases.

Table 26.—Table of Bladder Wounds.

Association with Other Wounds	To Base	Died	Not Known
Small gut (resection); all intraperitoneal	—	4	3
„ „ (suture); one extraperitoneal	—	7	—
„ „ (resection); colon anus ..	—	1	—
„ „ („); rectum (suture)	—	1	—
Colon*	—	2	1
Rectum .. .. extraperitoneal	—	1	—
Bladder alone injured { extraperitoneal	9	11	—
Bladder alone injured { intraperitoneal	2	3	—
Total ..	11	30	4

* Transverse colon, 1; pelvic colon, 1; wound of bladder extraperitoneal, 1.

Nature of Injuries.—These may be either intraperitoneal, or extraperitoneal, or both. The intraperitoneal lesions—perforations, tears, or slits—are very often not extensive. The extraperitoneal wounds, often accompanied by much hæmatoma, are slits or tears. They are usually situated at the sides of the bladder, and are often caused by bony spicules. The combined intraperitoneal and extraperitoneal injuries are usually caused by oblique wounds, the missile entering by the lower lateral part of the bladder and passing out through the peritoneal surface. Projectiles sometimes lodge within the bladder, and cause pain at a later period.

Treatment.—*Intraperitoneal wounds* are, as a rule, easily sutured, except those which occur at the very bottom of Douglas's pouch. The bladder should be explored for a foreign body. Suprapubic drainage is not necessary here. Catheterization for a few days may be necessary, or a catheter may be tied in, though this treatment is not to be continued for long.

Extraperitoneal wounds are treated by an incision down to the wound in the bladder, which latter may be sutured, if possible, and a drain left in the space formed by the operation. If the wound in the bladder cannot be sutured, it is most probable that a drain down to the wound will be sufficient; if there is any doubt, a suprapubic cystostomy is most probably the safest course.

Colonel Fullerton, who has had much experience of these cases at the base, does not think that a suprapubic cystostomy is necessary in extraperitoneal wounds, as he has often seen cases at the bases do well discharging urine through the various fistulous tracks caused by the projectile's entrance through the buttocks or thighs. He states, and justly, that urine is an aseptic fluid, and therefore need not be feared. It is quite true that many such wounds may reach the base; but at the front one sees cases wounded extraperitoneally do badly and show signs of septic intoxication; and after meeting with such instances one does not feel inclined to hold one's hand on the chance of the case running a favourable course.

Mortality and Causes of Death.—The uncomplicated bladder wounds show a mortality of 56 per cent, 14 deaths in 25 cases. Shock and hæmorrhage form the causes in the majority. Fracture of the pelvis seems greatly to

increase the shock, and wounds of the pelvic vein seem responsible for a great deal of the hæmorrhage.

In the case of complicated injuries the picture is dismal in the extreme. Most of these cases are intraperitoneal wounds, which in civil practice, and uncomplicated, are not greatly feared. It would appear that the increase in time necessary to repair the bladder, after other serious injuries have been dealt with, is able to turn the balance against the patient, for the mortality is much worse than in intestinal injuries alone.

PROTRUSION OF OMENTUM AND VISCERA.

By this is meant, not the exposure of the abdominal contents through a gap in the abdominal wall, but their prolapse through a wound, often comparatively small.

Omentum.—As would be expected, the omentum is most frequently seen in this connection. It appears in large or small amounts in wounds situated all over the abdomen, also in those, situated in both hypochondriac regions, where it reaches the outside of the body through interspaces or through broken ribs where one hardly would expect to see it. There are two methods of extrusion of the omentum. It is either (1) carried out by the projectile, or (2) driven out through the entrance or exit wound by the intra-abdominal pressure.

In one case, where a shell fragment had entered above the umbilicus in the mid-line and had come out in the right loin behind the lateral line of the body, the omentum was so firmly carried into the long oblique exit wound that it required considerable force to release it; it was, in fact, strangulated within the abdominal wall, though none of it showed externally.

Before operation became the rule, it was usual to leave these tags to slough off, and probably this is still the best course to pursue if the cases are seen late. If seen early, it is best to treat such cases as other abdominal wounds, and explore. In several instances where this has been done the intestine has been found wounded.

Stomach.—This has been found herniated by itself, and in association with the spleen, splenic flexure, and small intestine. In one case it was successfully sutured and replaced, though too much of the abdominal wall had been carried away to allow the external openings to be closed.

Protrusions of the upper viscera are accompanied by a good deal more shock than is protrusion of the small gut.

Liver.—This organ has also been partly herniated.

Small Intestine.—Next to the omentum, the small gut is most frequently herniated, and, as in the case of the omentum, it may be carried out or expelled. Sometimes a knuckle lying outside has been actually wounded; in other cases the extruded part has remained intact, but there have been numerous lesions in the small gut within the abdomen.

If seen early, the ordinary rules apply, and the abdomen should be opened and the lesions repaired; if seen later—over twenty-four hours—it is not probable that anything can be done, but still it is better perhaps to explore if the condition of the patient justifies it. A great deal of small gut can be

prolapsed without excessive shock. A man wounded six hours previously, with the greater part of his small gut on his belly wall, had a pulse of 100, and was in very fair condition.

Colon.—The transverse colon has been herniated, and in one case the gut was slightly herniated in the wound; as the injury was two days old, the constriction was relieved, and an artificial anus established.

ANÆSTHETICS FOR MEN WITH WOUNDS OF THE ABDOMEN.

By Captain GEOFFREY MARSHALL, R.A.M.C.

A patient with a penetrating wound of the abdomen usually shows signs of shock. In a typical case the face is pale, the extremities are cold, the pulse is rapid, and the blood-pressure below normal. If put to bed and surrounded with hot bottles, the man's general condition will improve. Both surface temperature and blood-pressure rise. It is important that heat loss should be prevented during the course of operation.

The Choice of Anæsthetic.—Men who have been wounded less than forty hours previously are not good subjects for spinal anæsthesia. Intrathecal injection of stovaine is followed by a great fall of blood-pressure, which may be fatal. Patients with wounds of the abdomen appear to present no exception to this rule. The writer's experience of spinal anæsthesia for these cases has been limited and unfortunate. Three patients were each given 0·07 grm. stovaine, and all died within a few hours of operation.

Chloroform is an unsuitable anæsthetic. The blood-pressure falls steadily during the course of the administration. If the operation is prolonged, the patient may die before the abdomen is closed, or during the next few hours.

Ether remains the drug most generally used. Good results have been obtained with open ether. Its chief disadvantages are: (1) The loss of body heat caused by the prolonged inhalation of cold vapour. This is especially noticeable in the theatres of casualty clearing stations, which are commonly tents or temporary buildings, difficult to keep really hot. (2) Irritation of the respiratory tract. This is most serious in winter, when many of the wounded have some bronchitis before operation.

Men wounded in the abdomen are particularly liable to develop bronchitis. This may be due to deficient movement of the lower chest. At this casualty clearing station, the proportion of cases which had bronchitis after operation was 54 per cent when open ether was used. With warm ether vapour the percentage dropped to 14·7. These figures were obtained from two comparable series of cases occurring in the same months of two successive years.

Ether should not be given by the intravenous method to men suffering from shock. In these cases profound collapse may occur within two hours of administration.

In our experience the most satisfactory way of administering ether or chloroform is by the Shipway apparatus. The patient inhales a warmed mixture of air and anæsthetic vapour. Induction is quiet and rapid; the absence of struggling may save much bleeding from wounded vessels. Breathing is easy and noiseless. There is a remarkable absence of secretion. The patient

recovers consciousness quickly, and vomiting is rare. It is usually possible to give fluids by mouth within two hours of operation. In lengthy operations it is an advantage to pass oxygen instead of air through the ether.

When the projectile has penetrated the chest as well as the abdomen, ether should not be used. It is apt to provoke fatal intrathoracic hæmorrhage. In these cases we have found the most successful method to be a preliminary injection of hyoscine gr. $\frac{1}{100}$, morphine gr. $\frac{1}{6}$, and atropine gr. $\frac{1}{100}$, followed by a minimal amount of warm chloroform vapour and oxygen.

It is not necessary to give atropine before a warm ether vapour anæsthetic. We have not found any advantage in doing so. In the majority of cases morphine should be withheld before operation, or given only in small doses. A man recently injured is particularly susceptible to further shock. This susceptibility is greatly increased by large doses of morphine.

Factors causing Fall of Blood-Pressure during Abdominal Operations.—During the course of an ether anæsthetic, the blood-pressure shows a tendency to rise. If there is much manipulation of gut and peritoneum, it will fall gradually. The process, however, may be continued for hours without the blood-pressure falling to dangerous levels. Exposure of gut outside the abdominal cavity produces a much more serious effect. If more than two or three feet of gut are exposed, the blood-pressure will commence to fall after a few minutes. It will continue falling rapidly until the gut is replaced. This effect is seen when great omentum only is exposed. Surgeons should be urged to make big incisions, and work as much as possible with the gut lying inside the peritoneal cavity.

Apart from copious hæmorrhage, there is one other procedure which causes rapid fall of blood-pressure. This is turning the patient on his side. The effect is only produced if the patient has been under the anæsthetic for a considerable time before being turned. At the end of an abdominal operation, for example, the patient may be in good condition. He is then turned on the right or left side, so that the surgeon may excise a wound in the back. In a few minutes there is a great fall of blood-pressure and the radial pulse disappears. It may be hours before the patient recovers this lost ground. The indication is that wounds of the back should be dealt with before laparotomy. Turning the patient produces no ill effect in the first half-hour of an ether anæsthesia.

CAUSES OF FAILURE.

Mental and Physical Strain.—It is commonly said that the surgeon in war has an advantage over his peace colleague in that his subjects are healthy young adults. This, of course, is true; but still there is the strain caused by days of watching and alertness, and nights when sleep is difficult, interrupted, or impossible to obtain. Then there is the exertion of battle, which, for the time being at any rate, obliterates all sense of fatigue, so that many men do not know how tired they are until some wound is received which prevents them going further. Next there is the journey to the casualty clearing station. Sometimes the men arrive practically asleep, and resent any interference or examination. Other men arrive in whom a state of excitement is still present, and they are willing and anxious to chatter about their experiences. Then,

after being fed they are dressed, and if they do not fall asleep in the process they do so immediately afterwards; and it is one of the most striking sights of the medical side of war to see a large room filled with men lying on stretchers, some slightly wounded, some severely, some mortally; but all asleep, and asking for nothing but sleep. It is on such patients that the surgeon has to work, and it may well be imagined how much the mental and physical strain may increase the effect of the injury.

Complicating Injuries.—One need add very little on this subject, except to say that every kind of bodily injury may be added to that of the abdomen. Compound depressed fractures of the skull, fractured long bones, multiple wounds, fractured spine, and avulsed limbs, are among such complicating injuries. In considering the total mortality, and in appraising the worth of abdominal surgery, one must take these injuries into account; it may be said that but for such extraneous injuries the mortality would be considerably lower.

SHOCK.

This can be considered under two heads: (1) Subjective sensations, (2) Shock proper.

1. **Subjective Sensations.**—The sensations of a man shot in the abdomen vary in a remarkable degree. As can be well imagined, the size of the projectile must have a considerable influence. The shell fuse-cap produces much the same effect as a violent blow from the heels of a horse, although there may be no open wound and the subsequent course proves that there is no visceral injury. A somewhat similar effect may be produced when a portion of the abdominal wall is torn away; but as the blow is a more or less glancing one, in such conditions the amount of 'knock-out' effect is often surprisingly little. Men have walked considerable distances with such wounds, their intestines supported by a dressing and bandage. To quote a case: A man had his abdominal wall ripped open by a bullet just as we were being compelled to evacuate a trench. He was bandaged up with a field dressing, and insisted on walking to a trench in the rear, where he lay on the fire step for some time until things became quiet and he was able to be taken away to the ambulance. He made a complete recovery.

Sometimes a man, though he knows that he has been hit in the abdomen, is quite unconscious that his intestine is prolapsed, although a considerable amount may be outside his body. Another case: A man was hit just above the pubes; he experienced very little inconvenience. When the first dressing was applied, some of the small gut lay on the belly wall. This was covered up with the dressing, and the man taken straight to an advanced abdominal hospital. When he arrived there he was in good condition, and in no pain. Six or seven feet of small intestine, perforated in places, lay under the dressing. He made a complete recovery after operation.

When a small missile penetrates and wounds the intestine, there may be very little pain or disturbance. One man, hit in the iliac region, in whom a subsequent operation proved intestinal injury, was quite unconscious that he had received a severe wound. He thought that he had been hit in the leg, the bullet having disturbed some of the lumbar nerves. Another man, a bearer

in the R.A.M.C., who had been wounded in the abdomen, and, as subsequent operation proved, in the intestine, was brought on a stretcher to an advanced dressing station; but, seeing there were many wounded to be attended to, he got up off his stretcher, and lent a hand. Another case may be quoted as showing how little distress a wound in the intestine may produce. It was one that I saw early in the war, and which confirmed my opinion that the expectant treatment was wrong. This officer had a side-to-side penetrating wound of the abdomen. When I saw him at a clearing station about six hours after receipt of the wound, he was in good condition, free from pain, cheerful, and smoking a cigarette. He was not operated on: he was dead of peritonitis in twenty-four hours. Post mortem, he had a single hole in his intestine.

On the other hand, a man shot in the abdomen by a bullet or one of the smaller projectiles may experience a tremendous blow which may knock him out. Now this sensation of a tremendous blow may be experienced even when small missiles hit the limbs. It is curious to remember that the blow or kick sensation is experienced by those who rupture muscle fibres while playing games. It is therefore legitimate to imagine that the sensation of a violent blow has nothing to do with an injury to the solar plexus.

Pain of an intense character is sometimes experienced immediately after the receipt of the wound, and it accompanies wounds both of the upper and lower abdomen. In the latter case it has been found to be specially connected with penetrating buttock wounds. The suddenness of the pain in these cases recalls that seen in perforated gastric ulcer, or appendicitis. This similarity suggests that the pain is connected with an irritation of the peritoneum by the bowel contents, although the escape of such matter may not be perceptible at the operation. Some people hold that the contents of the jejunum are more likely to cause pain than those of the ileum. The following case in an example of intense sudden pain, and a board-like rigidity which so often accompanies it. It should be noticed that the pulse was only 60. The patient was wounded in the back by a rifle grenade; he was admitted within four hours of the wound. His pulse was 60. He was pale, and suffering intense pain in spite of morphia. His abdomen was like a board. His distress was increased because, having been hit in the abdomen, he was quite sure he had got to die. He was taken to the theatre, and when examined, the only wound found was a small puncture on the outer side of the erector spinæ. Operation disclosed one abrasion and three perforations of the jejunum. There was no visible escape of contents. Recovery was uninterrupted. The fragment that caused the injury was no larger than a large safety match-head, and so small that its weight could scarcely be appreciated by the hand.

2. **Shock Proper.**—Everyone understands in a general way what is meant by shock, and has in his mind a picture of a patient in such a state. When asked to define what he really means by the word, he will very likely be unable to answer the question. As regards the abdomen, a state of clinical shock is produced in various ways: by a violent blow; by multiple intra-peritoneal abdominal injuries; by hæmorrhage; by sepsis, which seems to be of the nature of poison shock; and by pain.

If a man is hit by a large projectile, the blow will produce shock just as any other blow will do. The man is winded or knocked out. Again, extensive

injuries of the abdominal wall, especially in the upper part, with exposure of the viscera, will cause shock. This is also true of multiple injuries of the abdominal viscera; and there can be no doubt that the gravity of any case does rapidly increase with the number of lesions in the viscera and the number of viscera injured. Apart from these generalizations, it is very hard to make any definite statement as to the relation between the amount of shock present on the one hand, and the organs injured and the amount of individual damage on the other.

Some idea of what a man's state may be after a wound in the abdomen has been given when speaking of a man's subjective sensations, and it can there be seen that, immediately after the receipt of the wound that proves fatal, a man may for a considerable time be able to pursue what he was doing. I may quote here another case illustrating this: A flying man, well over the German lines, was hit by a high-explosive shell; the missile entered a little way behind the anterior superior spine, traversed the abdomen, caused two holes in the small intestine, and then lodged in the areolar tissue behind the pubes. The man brought his machine back, made a good landing, and was brought into the casualty clearing station near by in really first-class condition. He was operated on, and the wounds in the intestines sewn up; he died within forty-eight hours of acute sepsis arising from the retroperitoneal tissue.

There is considerable difficulty in ascertaining the connection between the actual damage done and the amount of shock. Regimental medical officers who see the cases early can form no idea what the extent of the abdominal injury is, apart from the loss of abdominal wall or protrusion of viscera; and by the time the cases come to operation, there are the added facts of loss of blood and sepsis. The amount of shock seems to be largely due to the loss of blood; if one could only find some easy method of supplying this fluid, it is possible that our results might be very greatly improved.

A word may here be said about the effect of lesions of individual organs. It has been stated before that in the case of the liver one meets with some cases of shock which do not seem to be explained by the amount of damage or the amount of blood lost. Wounds of the spleen, even though severe, do not cause much collapse, apart from hæmorrhage. The same can be said of wounds of the kidney; but in certain instances they are accompanied by great shock, although recovery follows without operation.

The stripping up of the retroperitoneal tissue by blood seems to cause shock out of proportion to the amount of blood lost.

The great pain of a small injury will often produce pallor, collapse, and cold extremities while the pulse is quiet.

There is large scope for investigating this subject, and work is being done thereon, notably by Captain Geoffrey Marshall; but this is only possible in quiet times when medical men can be spared for the purpose. It is not a question of prevention so much as of cure, for it is impossible to apply the ordinary anti-shock procedure to a man before he is wounded. The clinical shock produced by sepsis is often very marked, and may cause death in a comparatively few hours. This, of course, is also well seen in cases that are dying of gas gangrene of the limbs.

HÆMORRHAGE.

Hæmorrhage stands out as the greatest enemy of the surgeon. It comes from all sorts of places: (1) The stomach-wall vessels; (2) The omentum; (3) The small-intestine wall; (4) The mesentery of the large or small intestine; (5) The retroperitoneal tissue; (6) The abdominal wall; (7) The abdominal vessels; (8) The liver, kidney, spleen, and their vessels.

1. **Stomach.**—Injury to the actual wall of the stomach apparently does not cause much hæmorrhage; but damage to the vessels running on the stomach wall before they penetrate it, and to the big vessels lying on the two curvatures, does give rise to very great hæmorrhage.

2. **Omentum.**—There may be a fair amount of hæmorrhage from this structure.

3. **Small-intestine Wall.**—This is a source of considerable hæmorrhage, and in this way is perhaps a contrast to the stomach wall.

4. **Mesentery.**—The mesenteric vessels give rise to very considerable hæmorrhage. A mesentery wound includes also a wound of the big vessels, such as the colics, and it is most probable that hæmorrhage from these vessels is the most common source of blood in the abdomen when the cases come to operation.

5. **Retroperitoneal Tissue.**—Here hæmorrhage is a source of great trouble; it often raises the posterior abdominal peritoneum so as to touch the anterior wall when the abdomen is open. It may look like a large purple intra-abdominal tumour. This surface shows cracks through which the blood oozes slowly. If left, it may become infected and the seat of gas production. If, on the other hand, any attempt is made to find the bleeding point, the difficulty may be very great, even if the surgeon is successful. Whether this attempt is made must depend on the situation of the hæmatoma and the likelihood of injury to the big vessels. Most probably the best thing is to leave it alone, or to drain it through the loin if sepsis supervenes. There is often considerable shock, out of proportion, I should say, to the amount of blood lost. The sources of bleeding are the local vessels, and sometimes the renal vessels or pelvic veins, or even the abdominal cava.

6. **Abdominal Wall.**—In these cases the deep epigastric is the usual source of the trouble; and in one case the whole abdomen was filled from a wound of this artery.

7. **Great Vessels.**—The big vessels injured are the vena cava and the iliac veins, in addition to the renal and splenic veins. The abdominal cava has been closed by sutures by Captain Sampson, but the patient died. On another occasion the rent was successfully brought together by forceps by Captain Taylor; the forceps were left on for the time being, and the patient was sent to the base after their removal. The iliac arteries have been found wounded, and secured. So far no wound of the abdominal aorta has been found at operation.

8. **Solid Organs.**—The parenchyma of all solid organs bleeds freely at first; but it is probable that if no large vessel is injured, the hæmorrhage will cease spontaneously in a few hours (four to eight). In one case, however, the splenic pulp was still found bleeding after twenty-four hours.

Attention has already been drawn to the fact that wounds of the splenic and renal vessels are often not immediately fatal, though the hæmorrhage bursts out afresh directly the abdomen is opened, and the clots are disturbed. Although many cases of hæmorrhage become arrested spontaneously when no big vessel is involved, yet there is some amount of evidence to show that the blood may give rise to intraperitoneal trouble later, and for this reason an operation which merely cleanses the peritoneal cavity should not be classed as entirely useless.

The treatment of hæmorrhage after operation is not satisfactory, and repeated saline infusion is powerless to prevent a fatal issue. Transfusion of blood and of citrated blood has been tried, and cases have been published by Major Edward Archibald and Captain L. Bruce Robinson of the Canadian A.M.C. The cases are as yet too few to enable an estimate to be made of its efficiency in the class of case under discussion. Alexis Carrel says that saline infusion should always stop short of raising the blood-pressure to normal, and repetition of the infusion is better than one large infusion. Professor Bayliss has recently suggested that an infusion of colloidal solution most probably would be beneficial, as by this means the rapid loss of fluid from the vessels might be checked (*Proceedings of the Royal Society*, B, Vol. LXXXIX, 1916).

SEPTIC ABSORPTION.

This takes place in four ways: (1) From the peritoneum; (2) From the retroperitoneal tissue; (3) From the wound itself; and (4) From the operation wound.

1. **Peritonitis.**—There is nothing peculiar about the peritonitis, compared with that seen in civil practice. Perhaps one of the most interesting things is the fact that many patients have a remarkably good appearance, although their extremities are cold and they are practically pulseless. To look at them one would think that they could stand operation, but a further examination shows that this is obviously no good.

Peritonitis is the usual cause of death after the period of shock and hæmorrhage is over; death may occur within twenty-four hours, or be delayed for a week or ten days. The first variety may be called the fulminating type; the second the dormant. It was the latter class which was seen so often at the beginning of the war. These cases might or might not show signs of peritoneum involvement when first seen. If there were such signs, with rest in bed they would improve for a day or two, and give the impression that things were quieting down. There might have been some vomiting, but this often subsided, and the tongue kept clean. Then the abdomen became tumid. But the general condition remained fair, and the pulse, if somewhat rapid, was of fair quality. In some cases the patient then became obviously worse and died. In others the patients remained moderately well, or even appeared to be improved, and were sent to the base in consequence, with the belief that they would recover. In some cases the journey to the base seemed to light up the septic process, and they died soon after arrival. Others struggled on for some time further. One case may be mentioned in this connection: A man was shot in the abdomen, kept at a casualty clearing station for eight days, and then evacuated apparently doing well. On arrival at the

base he was ill, and was found to have a large iliac abscess, which was incised. He died on the following day. A post-mortem showed that into the fæcal abscess there opened two moderate-sized holes in the small intestine. It is a remarkable fact that in this case the bowels had acted normally on several occasions.

The amount of peritonitis present when operation is done at an early stage is very various, and within certain limits—to judge by the naked-eye appearances, which are known to be deceptive—it is not so dependent on the time elapsed since the wound as might be supposed. It has been found present in a marked degree in the case of a wound of the upper ileum after three and a half hours, and has been practically absent in the case of wounds of the jejunum after twenty-six hours. It is not altogether commensurate with the amount of fæcal escape. As regards prognosis, distention of the intestine is a better guide than the amount of visible inflammation. If the pulse is good when the abdomen is closed, the prognosis is good.

Peritonitis is, of course, brought about in some instances by contamination from the bowel; but one must remember that the projectile carries in dirt, even if it does not carry any clothing, and may in this way cause peritonitis apart from any bowel injury. The fatal micro-organism is the streptococcus. The anaerobes do not seem to be able to flourish in the abdominal cavity. In this way the peritoneum resembles the synovial sacs of joints. The projectile is often not found, and need not, I myself think, be sought for, though some people think otherwise. It is very difficult to find, and the search for it may result in a great waste of time.

The dissemination of infection is, I think, more a vital than a physical process, though of course septic fluid and stomach contents do gravitate to the pelvis. Bleeding of the mesentery, when in conjunction with a wound of the bowel, must have a definite influence in the spreading of infection. In two cases Captain Sampson had the blood in the abdomen examined, and this was full of streptococci.

A word may be said here about the progress of the patients after operation, putting aside those who do well from the first, and those who never look like recovering. The post-operative cases may be roughly divided into three classes: (1) Patients who do well for thirty-six hours or so, then go through a critical period, with abdominal distention, vomiting, and a rising pulse. They may eventually recover or succumb. (2) Those who are troubled by sickness continuing from the operation, but in whom the sickness diminishes and the pulse-rate falls. (3) Those who vary in an astounding manner from day to day, so that one can have no certainty of the ultimate result. This condition is often independent of the condition of the bowels, which may be acting. These are the cases spoken of by Sampson Handley in his paper in the *Lancet*, April 8, 1916. The cases referred to by him were those of pelvic peritonitis, in which the lower segment of the bowel is mostly affected; in the cases under discussion, unfortunately the infection was often in the upper portion of the abdomen. The two classes of case do not seem to be quite on a level, even if we admit that the dilatation of the upper segment is a septic and not a nervous phenomenon. However this may be, it is a most difficult point to determine whether operation is likely to do good or not. One sees so many patients go

through a critical period and recover, that one fears to proceed to secondary operation lest one might turn the balance against them. It has, however, been tried on several occasions, with very little success. If it is done, the method advocated by Sampson Handley seems to be the method of choice.

2. **Retroperitoneal Sepsis.**—A series of post-mortem examinations after abdominal injuries (made by Captain McNee and Captain Dawson) has demonstrated the frequency of retroperitoneal sepsis in cases supposedly dead of peritonitis or shock. It seems to be proved that this cause of death is much more common than one supposed. Gas was often found. The condition may occur in two forms, (1) gaseous, or (2) non-gaseous. It may occur with or without a bowel lesion, but more usually with. The colon is generally the portion of the bowel implicated, but it may follow wounds of the duodenum. The infection is often one of extreme virulence, so that a man on admission is dying, and this even with an open wound. In other cases it may follow a small innocent-looking wound in the flank. When, on account of symptoms, such a wound is explored, the retroperitoneal tissue may be black and stinking, or full of gas. At other times an incision shows only some blood-stained areolar tissue without smell. A simple incision may be all that is necessary, and the symptoms subside without any signs of violent infection. At other times the discharge becomes foul and evil-smelling, and the patient may succumb. Again, a loin wound may go on well for a time, then the patient may show signs of absorption, develop a fæcal fistula, and recover. At another time the skin of the loin becomes bronzed and crepitant, and the man dies rapidly in spite of incision. Bronzing of the skin is a curious manifestation, and its causation is not altogether obvious. In certain cases it subsides without any ill effects even if left alone; but it is so often accompanied by 'gas infection,' that it is well to incise it at the earliest possible moment.

It seems more or less of an accident whether these retrocolic infections develop gas or not, and I do not know that the formation of gas is a worse sign than its non-formation, if the ordinary signs of sepsis are present.

It is this sepsis which causes the high mortality in cases where a colon anus has been found necessary. Here the bowel has been widely wounded by the projectile, and the retroperitoneal tissue and muscles have been badly damaged. It seems impossible to stop such infection; by the time the case comes under treatment it has got too far ahead, even though the patient at the time does not seem gravely ill. Even widely open drainage seems impotent.

A rather striking manifestation of the gaseous variety is seen when a retroperitoneal hæmatoma becomes infected. This may be palpable from the abdomen as a well-defined tumour, but resonant on percussion. Exploration reveals the cause—a gaseous hæmatoma.

3. **Sepsis from the Projectile Wound.**—The wound caused by the missile may at any time show signs of sepsis and gas formation. In fact, it behaves just like the wounds of muscle in other parts of the body, and must be dealt with in the same way. It has caused death in a certain number of cases in which the intestinal lesion has been successfully dealt with. It used to be said that gas gangrene was not common in the trunk: my experience has convinced me that this immunity has been much overstated.

4. **Sepsis from the Operation Wound.**—This, too, becomes badly infected in many cases. The cause may be a faulty technique, but I think it is nearly always due to infection from the abdomen. This is not to be wondered at, when nearly all abdominal wounds are accompanied by blood effusion, which is itself grossly infective. Very often the operation wound is the seat of intense infection although the intestinal lesion does well. This is comparable with what is seen in the behaviour of the operation wound and peritoneum respectively in cases of acute appendicitis.

GENERAL STATISTICAL RESULTS.

Table 27.—SUMMARY.

Total number of cases	1288	
Arrived moribund	250	
Total mortality (excluding moribund)	50·06	per cent
„ mortality (including moribund)	60·2	„
Considered with view to operation	1038	
No operation considered advisable	73	
Total operations	965	
„ operative mortality	53·9	per cent
„ hollow-viscera mortality	64·7	„
*Stomach mortality	52·7	„
*Small-gut mortality	65·9	„
*Colon mortality	58·7	„

* Uncomplicated by any other intestinal lesion.

Table 28.—SHORT TABLE OF OPERATIONS, SHOWING ALSO THE NUMBER OF OPERATED AND NON-OPERATED CASES.

OPERATIONS	TO BASE	DIED
1. Suture of stomach	26	29
2. Suture of stomach and other operations on the intestinal tube	6	21
3. Resection of small gut	26	89
4. Resection of small gut and other operations on the intestinal tube not included in (2)	5	34
5. Suture of small gut	59	71
6. Suture of small gut and other operations on the intestinal tube not included in (2)	17	33
7. Formation of small-gut anus	—	7
8. For small-gut fistula	2	1
9. Suture of colon	50	52
10. Formation of colon anus	13	36
11. For wounded rectum (proximal colostomy not included)	3	5
12. Proximal colostomy	4	10
13. Cœliotomy, no hollow viscus perforated	89	33
14. Cœliotomy, liver wounded	76	38
15. Kidney, exploration of	25	7
16. Kidney, excision of	6	7
17. For wounded bladder	11	14
18. Spleen, exploration of	12	4
19. Spleen, excision of	4	12
20. Miscellaneous operations	10	18
21. No operation advised	69	4
22. No operation, moribund	—	250
Totals	513	775
Grand total	1288	

Table 29.—DETAILS OF OPERATIONS, ETC., SHOWN IN TABLE 28.

Note.—This table shows the number of individuals operated upon. In the case of the intestinal tract it shows the number of times the different parts were hit. The bladder and solid organs only appear in the table when they were the principal viscera damaged. To ascertain the number of times they were injured, the body of the article must be consulted.

Operations	To Base	Died	Total
Suture of stomach	26	29	55
„ „ and small gut	4	6	10
„ „ and small gut; gastrojejunostomy	—	2	2
„ „ and great gut	2	3	5
„ „ and colon; gastrojejunostomy	—	1	1
„ „ small gut, and colon	—	3	3
„ „ resection of small gut; gastrojejunostomy	—	2	2
„ „ and colon; resection of small gut	—	1	1
„ „ resection of small gut; gastrojejunostomy; colon anus	—	1	1
„ „ colon anus	—	2	2
Resection of small gut; circular enterorrhaphy	18	69	87
„ „ lateral anastomosis	8	18	26
„ „ gastrojejunostomy	—	2	2
„ „ suture of colon	4	17	21
„ „ colon anus	1	14	15
„ „ suture of rectum	—	3	3
Suture of small gut	59	71	130
„ „ and colon	16	26	42
„ „ resection of colon	—	1	1
„ „ colon anus	1	5	6
„ „ and rectum	—	1	1
Small-gut anus	—	7	7
„ fistula	2	1	3
Suture of colon:			
Cæcum	8	5	13
Ascending colon	13	12	25
Hepatic flexure	7	9	16
Transverse colon	5	8	13
Splenic flexure	4	6	10
Descending colon	6	3	9
Pelvic colon	7	9	16
Colon anus	13	36	49
On rectum: intraperitoneal wounds	1	2	3
„ extraperitoneal wounds	2	3	5
Proximal colostomy	4	10	14
Cœliotomy: no hollow viscus perforated	77	30	107
„ non-penetrating wound	12	3	15
On liver	76	38	114
On kidney: exploration	25	7	32
„ nephrectomy	6	7	13
For wounds of bladder: Extraperitoneal			
Suprapubic cystostomy	6	9	15
Drainage of wound	3	1	4
Suture	—	1	1
„ „ Intraperitoneal			
Suprapubic cystostomy	—	1	1
Suture	2	2	4
For wounds of spleen: exploration	12	4	16
„ „ splenectomy	4	12	16
For fæcal abscess	1	6	7
For loss of belly wall	—	1	1
For prolapse of viscera	6	3	9
Tube to pelvis	—	4	4
For contusion of belly	—	2	2
Loin wound enlarged	3	2	5
No operation (no indication)	69	4	73
No operation, moribund	—	250	250

GUNSHOT WOUNDS OF THE ABDOMEN: WITH NOTES OF 63 CASES.

By Captain BASIL HUGHES, R.A.M.C. (T.F.)

Results so far obtained in the treatment of abdominal wounds during the present war have varied with different surgeons. This can in part be explained by the different conditions which obtain, viz.—

1. The distance behind the firing line at which efficient surgical treatment can be undertaken varies considerably for different parts of the line.

2. The condition of the roads is worse in some parts than in others.

3. Some of the wounds are received during quiet times, others during an advance.

4. Some surgeons elect to operate upon cases that others leave alone, and their cases may in consequence show a higher percentage of mortality.

My own experience has brought me in touch with all the medical units as far back as the casualty clearing station, as I was over twelve months with a regiment, some months with a field ambulance, and I acted for three months as operating surgeon at a casualty clearing station during the recent fighting.

The early experience with a regiment has been invaluable in giving me an insight into the conditions under which the men exist prior to receiving their wounds, and also in affording opportunities of observing unique cases of wounded men who die in the line, or at the regimental aid post, and so never reach a clearing station.

Penetrating wounds of the abdomen, with the exception of those complicated by severe intraperitoneal hæmorrhage from whatever cause, do not at once—or indeed for some hours, if kept quiet—give rise to the abdominal symptom-complex. These symptoms are present by the time the wounded man reaches the clearing station, and after the motor journey this is not to be wondered at. Though the following cases are not included in the series which came under my care at the clearing station, I am quoting them to illustrate how long shock may be delayed even after the most fatal wounds.

Case 1.—Caused by trench mortar bomb. Anterior abdominal wall in great part torn away, with complete prolapse of the intestines, which were apparently intact. I saw him almost immediately after it happened. Pulse was slow, regular, and good. He talked sensibly, and having seen his own viscera, asked if they belonged to him. He drank some brandy and smoked a cigarette. This state of things lasted for fifteen minutes. On trying to fix him up with shell-dressings he quite suddenly collapsed, and died in a few minutes. The change was remarkably rapid.

Case 2.—Large shell wound which tore open the greater part of the anterior abdominal wall. Complete prolapse of intestines followed. Five minutes after injury the pulse was 88. The man was conscious and talked sensibly. The viscera were covered as well as could be under the conditions, necessitating some handling, which rapidly induced collapse and death.

Case 3.—Abdominal wall torn open by bomb, exposing viscera, which prolapsed through the wound. Pulse 88 five minutes after injury. No symptoms of shock. He asked for a drink, which was given, also strychnine and morphia. The viscera were covered over. He talked sensibly, expressing himself strongly about the German who had done it. Shock set in after seventeen minutes, and he died a quarter of an hour later.

These are three cases taken at random from hurried notes made at the time. The class of case puzzled me, and later I made the following comment in my note-book: "In cases of extensive damage to the anterior abdominal wall, where viscera were completely or severely prolapsed, it is difficult to explain the *latent interval*, varying from five to twenty-five minutes, in which the man is cheery, talking, smoking, and able to drink. This is followed by intense collapse, which appears quite suddenly, and death rapidly follows. In not one of these cases was peristalsis observed in the prolapsed viscera. The pulse and circulation in the mesentery were good. A hot cloth, had it been handy, would have been useful perhaps in these cases, as the sudden collapse was invariably associated with handling the viscera, but this was impossible under the conditions." I cannot but think that the majority of penetrating wounds of the abdomen are followed by arrest of gut peristalsis, and unless the gut is full of liquid material at the time, extravasation will be small. Whether stimulation, such as handling the gut, or the shaking in a motor, can set up peristalsis in an injured viscus requires confirmation, but from results it would seem probable.

It has been proved to my satisfaction that if these wounded men be carefully moved to a place of comparative safety near by—it may be an old trench, a shell-hole, or if lucky, a dug-out—given morphia, and made as warm as possible, they stand a far better chance of recovery than if hurried back to a casualty clearing station and submitted to immediate operation. I have many cases I could quote in support of the advisability of such expectant treatment.

There is one exception to what has been said above, and that is the case which is complicated by severe intraperitoneal hæmorrhage. Such men require immediate operation, and to be adequate and successful it must be undertaken much nearer to the firing line than the present casualty clearing stations. I have operated upon such cases in a dug-out situated in the communication trench, with a success that warranted the venture. This will be referred to later on. In this dug-out it was possible to give saline, and to keep abdominal cases if necessary.

During one attack a number of wounded had been lying out some hours. Amongst those who were rescued were a number suffering from penetrating abdominal wounds. These men, who were found lying in the prone position, complained of great thirst, but there was no typical peritoneal symptom-complex. During the recent fighting some cases have reached the clearing station which have lain out. Some of these developed fæcal fistula, others have had an action of the bowels containing changed blood a day or two after admission. They recovered without operation, and went down the line. One case I remember particularly well, and though it appears in the series, it will not be out of place to quote it here:—

The man was admitted twenty-two hours after injury caused by a very small piece of shell, which had emerged. Pulse 110, but good ; localized rigidity and tenderness in the region of the right iliac fossa. No vomiting. No peritoneal symptom-complex.

Laparotomy performed. Small intestine punctured in seven places. Plastic peritonitis, localized and well developed, and great omentum adherent. Fluid in peritoneum was reactionary. No escape of bowel contents. Wounds in gut sutured, tube inserted down to wounded gut and to Douglas's pouch. Wound in abdominal wall excised. Laparotomy wound closed with through-and-through sutures of silk-worm gut.

Pulse remained good for twenty-four hours after operation. Vomiting and distention then occurred, and death followed thirty-six hours after operation.

I feel strongly now that this operation should not have been done, and that if this man had been left alone he might have recovered, as his case did not differ in the least from a subsequent number of cases of a similar character which recovered without operation.

Without hesitation I make bold to say that lying out in an old trench, a shell-hole, or any convenient spot, distressing as it may sound, has been the salvation of a large number of men who have been hit in the abdomen.

The cases of men wounded in the abdomen during more quiet times, where it has been possible to see and attend to them soon after their injury, are still more striking. Though hollow viscera have been involved, there is a conspicuous absence of shock. Two such cases that I kept for forty-eight hours in a warm dug-out developed fæcal fistula. There was only slight distention, and with morphia they were comfortable. They were both sent down the line and, as far as I know, both men recovered.

Cases of injury to a hollow viscus, when seen soon after the infliction of the wound, provided they are not complicated by severe intra-abdominal hæmorrhage, show a definite and constant area of *localized tenderness*. This quickly becomes obscured by motor transport, and by the time the clearing station is reached, tenderness is generally diffuse, vomiting has commenced, and the pulse-rate increased.

Hence a large number of abdominal wounds, not complicated by severe intra-abdominal hæmorrhage, do not at once present symptoms of shock. Further, if not moved or subjected to motor transport, they remain comfortable for hours, and present no symptom-complex of peritoneal infection. They are thus far better able to stand the journey in a motor ambulance after administration of saline and morphia, together with rest, and their chances of recovery are thereby greatly increased. This practice I adopted wherever possible in the line ; I also marked the localized area of tenderness on the abdominal wall, in case it became obscure owing to transit.

Initial Points to be considered in Cases of Abdominal Wounds.—

1. *Fatigue.* This condition militates greatly against all classes of wounds, especially abdominal. Though not generally recognized, fatigue is probably the greatest predisposing cause of all trench ailments. I pointed this out in a paper published in the *British Medical Journal* on the condition known as "Trench Foot," and also in a paper published in the *Lancet* on "Trench Pyrexias." The length of time a man has been in the trenches, and the conditions existing in those particular trenches, are two important points to be borne in mind in dealing with abdominal cases.

2. *The interval of time that has elapsed since food.* During an attack, food is necessarily taken irregularly. The wounded man may have been several hours without food, in which case the hollow viscus may be empty when hit. On the other hand, it may be hit during the period of active digestion, when there is the added fear of extravasation and hæmorrhage.

3. *The nature of the food the soldier has been eating.* This may be bully beef and biscuits, or the ration issued during quieter times in the trenches. In the former case, extravasation has been neither so extensive nor so serious.

4. *The time at which the bowels were last opened.* In the trenches there is a tendency for men not to go to the latrine. A number have been hit while there, and the whole surroundings seem to have an inhibitory effect on defæcation. Consequently, when a man is hit, he may have three or four days' accumulation of waste matter in the large bowel. In almost all the cases on which I have operated, scybalæ as hard as bricks have filled the large bowel and rectum. The presence of these hard scybalous masses in the large bowel form one of the most difficult complications to deal with in the after-treatment. They cause distention and a large degree of obstruction, and call for the use of frequent enemata; on more than one occasion I have had to insert a finger into the rectum and remove large quantities, a procedure which is painful and distressing to the wounded man.

Were it possible to administer a good aperient to every man forty-eight hours before going into action, it would greatly favour the chances of those hit in the abdomen.

5. *The type of missile used.* Shrapnel balls, and pieces of high-explosive shell, are more serious than rifle or machine-gun bullets.

6. *The presence of early shock.* This almost always denotes intraperitoneal hæmorrhage of a severe kind; these cases are most serious, and will not stand a motor journey.

7. *The presence of complicating wounds.* Such are compound fractures of the extremities, ribs, or innominate bone, and wounds involving the thorax or spine. The latter are not uncommon when the missile has entered the peritoneal cavity from behind.

8. *Position of most comfort for transit.* Men with abdominal wounds prefer the prone position, and travel best this way on a stretcher.

Problem of Transit. This will depend upon whether an advance is in progress, or whether the troops are just holding the line.

During an advance, little can be done at the regimental aid post beyond giving morphia. These men have to be carried over rough ground, thence down a communication trench, often under heavy fire, to the advanced dressing station, which is some distance from where the wounded man fell. At the advanced dressing station, again, little can be done, owing to the presence of other wounded. From here they are moved on by motor ambulance to a field ambulance, and thence to a clearing station. Roads may be bad, the condition on arrival at the clearing station is grave, and the chances of recovery are jeopardized.

During quieter times an abdominal case can be kept for some time at the regimental aid post, warmed up, and given saline. The journey to the

clearing station can be made more gradual, and the chances of recovery are thereby increased.

It should never be forgotten that some men have morphia in their possession, and have already dosed themselves when found in the place where they fell.

The Conditions at the Clearing Station.—During an advance many cases are arriving more urgent than the abdominal. Such are hæmorrhages, severe lacerations of the limbs needing immediate amputation, and cases of gas gangrene calling for similar treatment; and these render the operating theatre in a condition which in civil life would be considered unsuitable for performing laparotomy. The energies of the operating surgeons are severely taxed, and this cannot favour the best results. When the pressure is not so great, more time and care can be given to abdominal cases, consequently their chances are more favourable.

Diagnosis.—Moribund cases arriving at a clearing station with a rapid small pulse, pale, sweating, and distended and dull in the flanks, are invariably cases of intraperitoneal hæmorrhage. Too often they die soon after arrival; some arrive dead. Those operated upon invariably succumb shortly afterwards. The cases of this kind that I was concerned with died during the interval in which efforts were being made to improve the pulse and general condition prior to operation.

Injuries to hollow viscera show fairly constant symptoms: pulse varying from 90 to 110; abdominal rigidity with retraction; general tenderness, rarely localized after a motor journey; persistent vomiting of a greenish-yellow material—this symptom has proved to be significant and important in connection with wounds of hollow viscera; no passage of flatus or urine; and a peritonitic facies.

Purely thoracic injuries resemble in some respects abdominal injuries. They differ in that these patients do not vomit persistently. The abdominal rigidity is unilateral, corresponding to the same side as the chest wound. Urine and fæces are passed. There may be hæmoptysis and cyanosis, with cardiac displacement, and respiratory embarrassment, with a short irritating cough. It should, however, never be forgotten that a chest wound may involve an abdominal viscus.

A wound in the back resulting in a retroperitoneal hæmatoma is often very difficult to differentiate from a penetrating wound of the abdominal cavity. Laparotomy has been performed for this condition, and blood has been found free in the peritoneal cavity, although the peritoneum has itself been uninjured. In these cases it is rare to find retraction of the abdominal wall. On the contrary, distention of the gut is present, of an apparently paralytic kind, which recovers in five or six days' time. I performed laparotomy on two such cases, and in both this paralytic condition of the gut with distention existed, although the gut itself was uninjured. It seems possible that the condition may be due to trauma of, or pressure of extravasated blood upon, the retroperitoneal plexuses. Vomiting, sometimes persistent, goes with this condition. There is not the same superficial tenderness to palpation, and rigidity is present to a lesser degree. It is often easy to palpate the posterior abdominal wall, and it is then that tenderness

is elicited. The peritoneum clothing the posterior abdominal wall is here affected; whereas in the wound of a viscus, both anterior and posterior layers are concerned, giving rise to greater rigidity and more superficial tenderness. This has appeared the most reliable means of differentiation between the two conditions.

Wounds of the anterior abdominal wall which do not penetrate the peritoneal cavity may be associated with damage to a viscus. One case had a severe tear in the liver, and in another case the cæcum was torn. In all cases of injury to the abdominal wall not involving the peritoneal cavity, it is wise to wait a few hours and watch for developments. If complications of an internal kind do not arise after three or four hours, the wound can be treated as the case demands.

Wounds of the thorax, thigh, buttock, and perineum may involve the peritoneal cavity, and this should always be borne in mind.

Classification of Abdominal Wounds.—The following classification embraces most of the forms of abdominal injury seen in the present war:—

1. Cases associated with severe intraperitoneal hæmorrhage.
2. Extensive injury to the abdominal wall, with complete prolapse of intestine.
3. Slighter injury to the abdominal wall, with prolapse of omentum and a portion of gut: (*a*) With perforation of the prolapsed gut; (*b*) Without perforation of the prolapsed gut.
4. Cases where the missile has penetrated the abdominal cavity and has not emerged (it is here that a localized area of tenderness is so helpful to the surgeon).
5. Penetration of the abdominal cavity, with inlet and exit wounds, or where the missile is lying beneath the skin instead of having emerged. In this class the course or track of the missile is known.
6. Penetrating wounds of the peritoneal cavity distant from and apparently having no connection with the peritoneum—e.g., the buttock, thigh, perineum, scrotum, and upper thorax.
7. Extensive wounds of the buttock involving the rectum and peritoneal cavity.

Treatment.—Treatment must necessarily start from the time and the place at which the man falls. When first seen, it may be impossible to move him, and all that can be done is to take away the water bottle, loosen his kit, and give morphia. These cases can as a rule be moved after dark and taken to a place of shelter from missiles.

Often, when there are many wounded to deal with, abdominal cases drift down with the rest to an advanced dressing station, where their wounds are attended to, and from this place they are hurried to a field ambulance, and thence to a clearing station. At other times, when fighting is not in progress, the regimental medical officer can give the case more attention. The cases suffering from severe intra-abdominal hæmorrhage stand moving so badly that, if possible, it is wiser to keep them and to operate in a dug-out near by where they fell.

In one part of the line I had a dug-out built in a communication trench, to which a wounded man could be brought in from four to five minutes after

receiving his wound. It was a necessity, as badly wounded cases could not be taken back in daylight, because this meant going over the open in view of the German lines. Here it was possible to undertake not only abdominal operations which were immediate, but also urgent amputations and operations for the arrest of serious hæmorrhage. Six abdominal cases associated with severe hæmorrhage were operated upon, and two recovered. This was a recovery of 33 per cent in cases which I am certain would never have reached a clearing station in time for anything to be done. Cases of amputation did well, and I heard of the men operated on subsequently in England. This operating dug-out was kept warm with a brazier, and an antiseptic technique was followed. Two cases of serious hæmorrhage from the middle meningeal artery were trephined, and the artery was tied. In both of them compression symptoms were rapidly becoming more profound, and demanded immediate treatment. I heard nothing further of these cases after they had gone down the line, except that they were conscious and well when they left the field ambulance. This proceeding sounds primitive, but results justified the venture, and no doubt life was saved.

I would like to mention in passing something that sounds more primitive still. On more than one occasion I have been called upon to perform amputation in the front line trench in order to prevent death from hæmorrhage. My friend, Captain Burke, has done likewise. In some of these cases it has been impossible to give an anæsthetic; yet these wounded men have seemed to be insensitive to pain if the operation was performed a few minutes after the injury. The cases all recovered and did well.

These results must teach us that it is not only possible to operate under such conditions, but that it is the correct practice in order to save life.

These men, after operation, would sleep under morphia despite the noise of the artillery, which was constantly kept up in this part of the line. Cases of injury to a hollow viscus were kept in this dug-out, where they were got warm and given morphia and saline. After some hours they were carried to the advanced dressing station, and arrived at the field ambulance in good condition. This early rest, with saline and morphia, is highly desirable, giving the omentum and peritoneum time to start their protective work.

On reaching the casualty clearing station, abdominal cases should be put into a bed with as little delay as is possible, and after a preliminary examination it is wise to wait three or four hours. This will give the surgeon an opportunity of finding out which way the case is going, and at the same time it gives the wounded man a rest after the motor journey. Should the pulse-rate increase, and vomiting of a persistent type set in or continue, and be associated with abdominal rigidity and tenderness, then operation should not be delayed. If, on the other hand, there is little vomiting, and the pulse-rate remains at what it was on admission, it is wiser to wait.

If the missile is retained, and especially if its position be suspected to be retroperitoneal, a radiograph should be taken, in order to guide the surgeon in his search for it. The removal of the missile, especially a shell fragment, is most important, as a fatal infection is almost certain to ensue if it is left.

Expectant Treatment.—If the pulse-rate has not increased after two or three hours' rest in bed, and the patient has warmed up and become more

comfortable, and especially if vomiting of a greenish-yellow material is not frequent or persistent, then it is quite justifiable to wait. After further waiting the pulse-rate may fall and its quality improve; with this the intra-abdominal lesion is becoming localized. Sips of water may be given by the mouth, and this is supplemented by subcutaneous saline. Bismuth carb., gr. x, is given three times a day, and tinct. camph. co., min. xv, combined with it seems to have a beneficial effect in these cases. The abdominal wound should be dressed frequently with peroxide of hydrogen and eusol, and should be carefully watched for infection. The temperature should be taken four-hourly.

These wounds may or may not give rise to serious infection. If there is any reason to suspect its existence, it should be surgically dealt with without delay.

At the end of forty-eight hours, one of the following conditions may be present: (1) Pulse-rate fallen, and pulse quality improved; presence of a definite localized tender area; little distention, and vomiting ceased; urine passed, and perhaps some flatus. (2) Pulse-rate rising after a temporary fall; distention, and persistent vomiting of an obstructive type. Should the second of these conditions obtain, and it is apt to set in very rapidly, then operation should be performed without delay.

Vomiting.—Three types of vomiting associated with these cases call for comment:—

1. Vomiting on admission, and aggravated by motor transport. Such vomiting may be persistent, or it may get less and cease entirely. The cause is reflex, and it has invariably denoted severe peritoneal irritation, caused by products of extravasation from a hollow viscus. Should it cease with rest in bed, the damage done is being adequately dealt with by the omentum and peritoneum. Should it persist, my cases have shown extravasation on a large scale, such as would be caused by a severe rupture of the small intestine while digestion was in active progress, rupture of the urinary bladder when full, and the like. Such persistent early vomiting is a grave sign, and calls for early operative treatment.

2. Vomiting which has ceased, and commenced anew after forty-eight hours' rest. Such vomiting is generally obstructive, and this obstruction can be traced to one of two causes: (*a*) Obstruction in the large gut due to the presence of the hard scybala already mentioned; (*b*) Obstruction as a consequence of plastic peritonitic adhesions having shut off the damaged gut. The first cause is the more common of the two, but I have seen both. The vomiting in type 2 is associated with distention, and so differs from that in type 1. Without any operation, I have seen this class of case develop a fæcal fistula, which has saved the surgeon the task of interfering, and at the same time has saved the patient. This type of vomiting if a fistula does not develop, calls for active interference; but the lesion is now shut off and localized, and the outlook is better.

3. Vomiting which is not peritonitic, and where there is no excessive distention. This form is toxic, and denotes grave infection in the wound. Vomiting associated with gas gangrene is well known and recognized, and is an extremely grave symptom.

Constipation.—On the third day an enema is given. The ordinary turpentine enema has been mostly used in these cases. Great perseverance is needed on the part of the sister, as the rectum and gut are usually blocked with hard scybalous masses. Sometimes, following administration of these enemata, a fæcal fistula has developed. Scybala are the greatest bugbear to the surgeon who undertakes abdominal work in this war. In the majority of cases they have been the cause of the obstruction following operation, far more often indeed than plastic peritonitis. The difficulty in getting the bowels to move after operation is well known to all surgeons at clearing stations, and further, how much such cases improve and get along as soon as these scybala have been evacuated. In most cases of obstruction setting in at the end of forty-eight hours upon which I have operated, the obstruction has been *below the seat of injury in the small gut*, and has been traced to a large accumulation of scybala in the large gut. In only a few cases did I see obstruction due to plastic peritonitis. Some surgeons have prescribed calomel, pituitrin, etc., soon after operation, and fæcal fistulæ have resulted; this again tends to prove that the obstruction is lower down, the bowel giving way at its weakest point, namely, where it was sutured.

Retroperitoneal wounds accompanied by paralytic distention of the gut respond well to pituitrin, eserine, and calomel. In two such cases fæcal fistulæ developed, and discharged through the wounds. They followed the administration of a turpentine enema. Both cases did well, and passing fæces both by fistula and rectum, went down the line. It is important in these cases to extract the missile—which is often a piece of high-explosive shell—and also the piece of cloth it has carried in.

Operative Treatment.—Cases of severe intraperitoneal hæmorrhage reaching a casualty clearing station generally die soon after admission if they survive the journey; operation only seems to hasten their end. If such cases are to be saved, operation should be performed at once, and much nearer to the firing line than the casualty clearing station. Fatigue, mental complications, motor transport, coupled with other wounds which complicate the abdominal injury—especially thoracic wounds—all add to the surgeon's difficulty and militate against the patient's chances. The wound may be foul on admission, and the other complicating wounds may also contain serious infection; hence these cases on arrival are suffering in addition from a degree of bacterial toxæmia.

The operating theatre in which I worked was an unpainted wooden hut. Often an amputation for gas gangrene has been in progress on a table two or three feet away, and on the other three tables septic wounds and fractures have been receiving attention. Laparotomy under these conditions would be condemned at home; yet necessity demanded it in these cases, and what is still more strange, no harm came of it. Cases of acute appendicitis have been operated upon under the same conditions, and have healed by primary union. This goes to show that whatever the surroundings, laparotomy may be undertaken in safety if the surgeon's technique is sound.

The anæsthetic employed has in all cases been open ether after chloroform induction. I have avoided preliminary injections of any kind in the form of morphia, atropine, etc. In some cases ether has been administered intra-

tracheally by Captain L. Game, and from the influence of such an anæsthetic on the after-progress of the case it can be strongly recommended; to the surgeon the anæsthesia is more uniform, and the diaphragmatic movements are damped, making operation more easy; while the patient is benefited by being saved the energy required for increased respiratory excursions brought about by ether inhalation. During the operation, continuous saline solution is slowly run into the subcutaneous tissues of the axillæ until two pints have been absorbed.

The actual time taken in performing the necessary operation should be as short as possible; in most of these cases it did not exceed half an hour. Prolonged operations are borne very badly by these wounded men, and any additional shock should be avoided. Never before this war have we recognized what a friend the surgeon has in the great omentum and peritoneum if he will use them aright.

The abdomen is shaved, cleansed with ether, and painted with iodine. The incision is determined by the area of maximum tenderness; if possible a paramedian incision is employed.

Cases with Prolapsed Gut where the Gut is not Perforated.—The wound is carefully excised around the prolapsed gut. This is then carefully washed with warm saline, returned, and the abdominal wall repaired. The skin incision is better left open for a day or two.

Cases with Prolapsed Gut where the Gut is Perforated.—It may be possible to stitch the perforation and cover it with an omental graft, and after careful washing of the intestine with saline, to return it, with a rubber tube inserted down to the wounded gut. If, however, this is badly damaged, and dirt has been carried into its walls, it is better to resect the damaged portion and perform an end-to-end anastomosis.

Cases where the Missile has Penetrated the Abdominal Cavity and has not Emerged.—Three factors have to be considered here: (1) Excision of the wound if possible; (2) Repair of damage to hollow or solid viscera; (3) Removal of the missile. It may be possible to include the excision of the original wound in the laparotomy incision; but if not, it is best first to excise the wound, and after covering it with gauze steeped in some suitable antiseptic, proceed with a clean scalpel to open the abdomen.

Repair of Damaged Gut.—

1. Single perforations, generally present in the cæcum, hepatic flexure, splenic flexure, or other part of the large bowel, are rapidly sutured with fine thread, and an omental graft fixed over this with a stitch or two. Sometimes an omental graft has been sufficient in itself, and I have used it twice in perforation of the hepatic flexure, with good result.

2. Multiple perforations are generally found in the small gut, and the choice of operation lies between: (*a*) Suture of the separate perforations; (*b*) Resection of the damaged gut, with end-to-end or lateral anastomosis; (*c*) Enterecto-enterostomy. Wherever possible the first procedure is to be recommended, as resection is a big undertaking in these patients, and too often proves fatal. The second method is called for when the mesentery is badly involved, or where the damage to the gut is so extensive as to render suture impossible. The third procedure is called for when the condition of

the wounded man will not warrant resection being undertaken. It can be done rapidly, and involves much less handling.

After multiple suture of the gut a fistula is liable to develop, if efforts are made to induce peristalsis. In addition to suture in these cases I have always carefully wrapped the great omentum around the damaged gut, and fixed it with a suture. It is a rapid procedure, and is a safeguard against fistulæ.

Injuries to the Liver have either been sutured, if large, or packed with gauze, which is removed at the end of forty-eight to seventy-two hours. In one case a piece of high-explosive shell and clothing was removed from the liver, and gas exuded.

Wounds of the Bladder.—These are accompanied with extravasation of urine into the peritoneal cavity. A catheter is first inserted per urethram and tied in. The extravasated urine is mopped out, and an omental graft fixed over the hole in the bladder. These wounds have done remarkably well with this treatment. The catheter is removed in forty-eight hours' time, and the tube to Douglas's pouch at the end of seventy-two hours. These patients have passed their urine without trouble. Urotropine, gr. x, by mouth is given thrice daily, and no complications have followed. It would seem that the bladder wall heals rapidly and soundly.

Treatment of the Peritoneum.—All extravasated matter is carefully mopped up with dry gauze, and peritoneal lavage has not been practised in any of these cases. One large rubber tube has been inserted into Douglas's pouch or the kidney pouch as the case demanded, and one down to the wounded viscus. After closure of the abdominal wall, ether, 2 to 3 ounces, has been left in the peritoneal cavity, and I have seen great benefit result from its use. The missile should be sought for and removed. In some cases it has been found surrounded by great omentum; in other cases it is lying free in the abdominal cavity, generally at the bottom of Douglas's pouch.

Extensive Wounds of the Buttock involving the Rectum.—Extensive buttock wounds in this war have been very fatal; they seem excessively prone to the virulent infections with which all wounds are complicated, and infections in the buttock tissues run a more virulent course. Left inguinal colotomy has proved the best treatment, with constant irrigation of the lower limb of the gut with boracic lotion, the fæcal current being diverted from the injured rectum and buttock. It would seem that colotomy might be performed with benefit in all cases of extensive injury to the buttock not involving the rectum, but involving the innominate bone.

It may be a coincidence, but it is worth mentioning, that two of the worst buttock wounds I saw became accidentally flyblown and were soon alive with maggots. They both recovered, and improvement commenced on arrival of the maggots. It is a recognized fact that *B. aerogenes capsulatus* and *Streptococcus fæcalis* do not exist in the same wound with maggots, and of the two conditions the latter is by far the lesser evil.

Closure of the Abdominal Wall.—I have in almost all my cases closed the abdominal wall with through-and-through sutures of silkworm gut, and have included drainage tubes. Where I closed the wound in three layers, I got trouble in the form of serious wound infection, and consequently these cases did badly.

The laparotomy wounds, whatever care be taken, are extremely prone to become septic, and I think the following reasons account for this: (1) The diminished resistance to infection these patients possess, owing to fatigue and the shock of transport; (2) Septic material has been carried in with the missile, and the patients are suffering from a degree of toxæmia; (3) Extravasation of intestinal contents has already taken place into the peritoneal cavity. This gangrenous infection of the wound sets in with remarkable rapidity, often a few hours after the operation.

Infection of the laparotomy wound is prone to follow gunshot wounds of the back associated with retroperitoneal hæmatoma. My own experience goes to prove that the use of drainage tubes, with through-and-through sutures of silkworm gut, is advisable to prevent this occurrence. A tube is also a safety valve in case a fistula should develop, and this has occurred on more than one occasion.

It might be argued that infection of the abdominal wall is due to faulty technique, but those with experience at casualty clearing stations will agree that these cases differ from anything we have ever before encountered. Cases of acute appendicitis, some complicated by abscess, have been operated upon in the same theatre and under the same conditions, yet these have healed by primary union. Those associated with abscess have taken no different course from what we see in civil life. I would mention again that in the cases where tubes were used, and through-and-through sutures employed, this gangrenous condition did not occur.

AFTER-TREATMENT.—The three days following operation are the most difficult and critical period of all. The operation, however skilfully and rapidly done, is only the first step towards a successful issue. Far more important is the after-treatment, and I ascribe the greater share of the credit in the successful recovery of these patients to the sisters who looked after them and who were so untiring in their care of them.

Complicating wounds require frequent dressings, calling for special care and skill. These patients are often extremely restless, and demand unlimited patience.

Two post-operative conditions which always call for immediate attention are: (1) Persistent vomiting of a greenish-yellow material; (2) Blocking of the large intestine with brick-like scybala, and abdominal distention. Persistent vomiting is best treated by stomach lavage with warm bicarbonate of soda solution (one drachm to the pint). This vomiting is associated with dilatation of the stomach; yet in only one case did symptoms of tetany appear. Abdominal distention and the presence of hard scybala are treated by frequent rectal enemata. With these enemata I have given eserine salicylate, gr. $\frac{1}{100}$, in three doses hypodermically at intervals of an hour, and pituitrin, and have seen no harm follow its use. It certainly seems to assist in keeping down distention and assisting in the passage of flatus. On the fourth day, providing vomiting has ceased, an ounce of castor oil is given by the mouth, and the bowels move without trouble.

I have made free use of subcutaneous saline for the first two days following operation. Sips of water are given by the mouth after vomiting has ceased, and bismuth carb., gr. x, with sodium bicarb., gr. x, are given three times a

day. For the thirst following operation I always give acid drops to suck. After the bowels have moved with an aperient, lightly boiled eggs and weak tea are given, and the diet is gradually increased. The abdominal wound is dressed daily, and shortening of the tubes commences at the end of forty-eight hours. On the seventh or eighth day after operation, sometimes earlier, these cases can be transferred to a base hospital.

Should a gangrenous infection occur in the laparotomy wound, the wound must be excised, cleansed with hydrogen peroxide, and salt-packed. The condition, when it occurs, is a grave complication. I have tried the anti-gangrene vaccine which has been issued for this infection, but have seen no benefit follow its administration.

The tables which follow contain a series of 63 cases. Of these, 45 were submitted to operation, 18 were not. Of the 45 who underwent operation, 17 died, giving a recovery-rate of 62 per cent; of the 18 not operated upon, 8 died, giving a recovery-rate of 55·5 per cent.

Of the 45 cases submitted to operation, 38 had received injuries to hollow viscera, and 16 of these died, giving a recovery-rate in cases of injury to hollow viscera of 58 per cent.

Of the 17 cases that died, 5 were complicated by penetrating wounds of the chest, 1 by a compound depressed fracture of the skull (the cause of death, which occurred nine days after operation, being encephalitis), and the remainder by compound fractures of other bones.

Abdominal operations performed in the front line are not included in this list.

In studying this series, it must be clearly understood that moribund cases, and cases obviously too ill to stand operation, were not touched. Every effort was made in these patients to try to improve their condition before submitting them to operation, and it was in this interval that some died, while others rallied.

If desperate cases which reach a casualty clearing station are going to improve, no harm can come of waiting. If their condition improves with waiting, so much the better; but should it become worse, why make their last hours more unbearable by submitting them to a useless laparotomy? The fact that one or two desperate cases have recovered after operation is no argument in its favour, for they might have recovered without; and it does not warrant laparotomy being adopted as a universal procedure.

SUMMARY.

1. Abdominal wounds complicated by severe intra-abdominal hæmorrhage should be operated upon immediately, and much nearer to the firing line than the casualty clearing station. An advanced dressing station, or a dug-out still nearer the line, has proved quite satisfactory. They should not be subjected to motor transport until hæmorrhage has been arrested (the same principle applies to badly torn limbs and hæmorrhage from large arteries).

2. Other abdominal injuries, involving hollow viscera, do not, if kept quiet, exhibit symptoms of shock for a long time. Even in most severe and

fatal wounds involving complete prolapse of viscera, shock has been delayed for as long as twenty-five minutes, and has only set in after the necessary dressing of the wound.

3. It is possible that in wounds of the abdomen involving the gut, peristalsis is temporarily arrested, but can be excited by the shaking occasioned by motor transport to a clearing station. Hence cases which have been kept quiet for some hours and given morphia and saline prior to the journey, are better prepared in every way to undergo operation if this be necessary. Subcutaneous saline acts as a diuretic, and so gets rid of fatigue products.

4. Rest previous to a motor journey is still more important if the viscus is injured during active digestion, to avoid extensive extravasation and hæmorrhage. If kept quiet, omentum and peritoneum are rapidly active, and in a few hours the dangerous area is shut off.

5. The indications for immediate operation on arrival at a clearing station are persistent vomiting of a greenish-yellow material, increase in pulse-rate, retracted rigid abdomen, and general abdominal tenderness. If these symptoms are not present it is wiser to wait.

6. Should improvement begin to show itself with waiting, vomiting setting in after forty-eight hours, or perhaps earlier, should be watched for. It is about this time that a fæcal fistula may develop.

7. Vomiting at the end of forty-eight hours may be obstructive, and due to scybala or plastic peritonitis, more often the former. Enemata, given frequently, will tend to relieve the vomiting due to scybala. It may be toxic, and due to serious infection carried in by the missile. Obstructive vomiting is accompanied by distention.

8. Operation should be performed as rapidly as possible, and every use made of the omentum to repair the damage to the intestine. Multiple suture of the holes in the gut has proved more satisfactory than resection and anastomosis.

9. Peritoneal lavage has not been practised, and ether, 3 ounces, left in the peritoneal cavity after operation, has had a beneficial effect in preventing post-operative intestinal inertia.

10. Closing the abdominal wall with through-and-through sutures of silkworm gut, and inclusion of rubber tubes, has given the best results, and these wounds have not become complicated by serious infection.

11. After-treatment aims at the prevention of obstruction and of post-operative intestinal inertia. Frequent enemata, gastric lavage, subcutaneous saline, bismuth carb., gr. x, t.d.s., with sips of water, and with this eserine salicylate, gr. $\frac{1}{100}$ subcutaneously, three doses at intervals of an hour, have proved most satisfactory.

12. For serious wounds of the rectum and buttock, colotomy is recommended, with washing through of the lower portion of the gut.

13. Moribund cases, and cases obviously unfit to stand laparotomy, were left alone.

[*See table on next page.*

ABDOMINAL WOUNDS

RANK	REGT.	WOUND	OTHER WOUNDS COMPLICATING	MISSILE	TIME ELAPSED
Private	Dorsets	Penetrated left lower abdomen from back	Nil	Shell	36 hours
Corporal	K.O.Y.L.I.	Right back, emerging left front	Nil	Bullet	36 hours
Sergeant	R. F. A.	Entry right abdomen; exit left abdomen below umbilicus	Nil	Bullet	16 hours
Private	R. I. R.	Entry right buttock; tender in left iliac fossa	Nil	Bullet	18 hours
L.-Corp.	Essex	Entry left iliac fossa	Nil	Bullet	?
Private	R. I. R.	Entry back, right; exit left flank	Nil	Bullet	?
Private	N. F.	Entry right of umbilicus; no exit	Nil	Shell	?
Private	K.O.Y.L.I.	Entry right of umbilicus; exit left	Nil	Shell	?
Private	R. I. R.	Entry left of umbilicus; exit back	Nil	Shell	?
Private	R. I. R.	Entry right flank; no exit	Nil	Shell	16 hours
Private	Y. & L.	Entry right abdomen; no exit	Nil	Bullet	? within 24 hours
Private	Wilts.	Entry left back; maximum tenderness in right iliac fossa; no exit	Nil	Shell	Within 24 hours
—	—	Entry to right and on level with umbilicus	Nil	Bullet	Within 24 hours

NOT OPERATED UPON.

SYMPTOMS, TREATMENT, SUBSEQUENT HISTORY, AND COMMENTS	RESULT
Very collapsed on admission; pain, distention, vomiting, pulse 108. Morphia gr. ½, water and bismuth by mouth. Two days later enema given; result good, but fæcal fistula of large intestine established in site of wound. Solid food started. Patient sent to base in good condition passing fæces both by rectum and by fistula. Had lain out	Sent to base
Collapsed; abdominal pain, tenderness, rigidity, abdomen moving very slightly; no urine or fæces passed; vomiting. Had lain out. Morphia gr. ½, water by mouth, bismuth. Dullness in left iliac region, fullness in Douglas's pouch, pulse 110. Distention followed. Pituitrin and enema given; fair result, with flatus; vomiting ceased. Same evening normal motion with changed blood. Improvement maintained	Sent to base
Pain, tenderness, rigidity, retraction, and immobility; pain later localized to left iliac region; vomiting; no urine or flatus passed; pulse 100, wiry. Morphia gr. ½, water and bismuth by mouth. Next day pulse 98 and good, vomiting ceased, no flatus passed, distention present. The day after pulse 90 and good, no vomiting, flatus passed, less distention, more comfortable. On next day small motion passed containing altered blood, patient much improved, still tender in left iliac region	Sent to base
Lay 14 hours between trenches. Rigidity, retraction, abdomen immobile, pulse 90 and good, no flatus or urine passed, vomited twice. Morphia, water and bismuth given. Next day abdomen moving better on right side, tenderness localized to left iliac fossa, flatus passed, slight motion with a little blood. Next day great improvement	Sent to base
Lay out 18 hours. Pain, general tenderness, rigidity, distention, dullness in flanks, pulse not perceptible at wrist; liver dullness present. Morphia and saline given before proposed operation. Died suddenly. No operation. Evidently hæmorrhage	Death
Lay out some hours. General pain, general tenderness, rigidity, distention, abdomen motionless; liver dullness present; dullness in flanks; very collapsed and pulseless and pale. Evident hæmorrhage. Morphia and saline, pending operation. Died. No operation	Death
Lay out 17 hours. Symptoms and treatment as above. Died. No operation	Death
Lay out 12 hours. Symptoms and treatment identical with above. Died. No operation	Death
Lay out 8 hours. Symptoms and treatment identical with above. Died. No operation	Death
Pain, tenderness, rigidity, vomiting; no flatus or urine passed; pulse 110; collapsed; tenderness left iliac region. Morphia gr. ½, bismuth, water. On second day flatus passed and blood in stool. Improvement maintained. Sent to base two days later	Sent to base
Pain, rigidity, abdomen motionless, distention, no vomiting; no urine and no flatus passed; pulse 110, small; dullness right iliac fossa. Morphia, water, bismuth by mouth. Slept. Next day slight flatus passed, distention, urine passed, most uncomfortable; definitely tender over right iliac fossa. Next day turpentine enema, pituitrin; large quantity of flatus passed and dark-coloured stool; patient much more comfortable; pulse 90, regular and good. Next day stool coloured black (? bismuth), flatus passed, distention down, patient better, abdomen moving	Sent to base
Pain, distention, rigidity, very little abdominal mobility, vomiting; pulse 115 and small; no urine or fæces passed. Morphia gr. ½, water and bismuth by mouth. No passage of urine or flatus 4.7.16. Turpentine enema. Flatus passed freely and dark-coloured blood with stool. No further vomiting. Patient much more restful 5.7.16. Distention less, bowels moved, abdomen moving better 6.7.16. Improvement still more pronounced. Sent to base	Sent to base
Pain, rigidity, retraction; pulse over 100, small; no flatus or urine passed. Symptoms almost identical with case of multiple wounds of small intestine in series operated upon which died. Morphia, water and bismuth. Distention followed in 48 hours, with biliary vomiting. Enema and pituitrin given, flatus passed 5.7.16. Water and morphia. Vomiting ceased, slight hiccough 6.7.16. Flatus passed, no vomiting, hiccough ceased, general improvement 7.7.16. Improvement further. Sent to base	Sent to base

Continued on next page

ABDOMINAL WOUNDS NOT

RANK	REGT.	WOUND	OTHER WOUNDS COMPLICATING	MISSILE	TIME ELAPSED
Private	Worcs.	Entry right loin; no exit	Nil	Shell	36 hours
Private	Wilts.	Entry left back; no exit	Nil	Shell	16 hours
Private	W. Y.	Entry buttock	Nil	?	16 hours
—	—	Entry thigh	Compound fracture of femur	Shell	20 hours
Private	A. I. F.	Just above pubis; prolapsed viscera	Large gunshot wound of thigh	High-explosive shell	12 hours

ABDOMINAL WOUNDS

RANK	REGT.	WOUND	OTHER WOUNDS COMPLICATING	MISSILE	TIME ELAPSED
Private	N. F.	Penetrating abdomen to left and just above umbilicus	Nil	Shrapnel	18 hours
Private	N. F.	Penetrating abdomen to left and below umbilicus	Nil	Shrapnel	20 hours
—	Dorsets	Gunshot wound of back going into abdomen	Nil	Shrapnel	18 hours

OPERATED UPON—*continued.*

SYMPTOMS, TREATMENT, SUBSEQUENT HISTORY, AND COMMENTS	RESULT
Pain general, great distention, motionless abdomen; vomiting. Lay out for 2 hours. No urine or flatus passed; no localization of tenderness, tenderness general; pulse 110, wiry. Morphia, bismuth and water 9.7.16. In early morning a feeling of wanting to evacuate and inability to do so. Enema given in afternoon; result, flatus and a small quantity of blood. In evening a fæcal fistula occurred in the wound, with much relief to the patient 10.7.16. Flatus passed, fæces passed by fistula and rectum, more by rectum than by fistula. Improvement continued. Sent to base	Sent to base
Pain general, tenderness general, had vomited before and after admission (green material), motionless abdomen, no passage of urine or fæces. Had lain out 4 hours. Distention; pulse 110 and wiry. Morphia, water and bismuth 5.7.16. Distention increased. Vomited once. Tenderness more localized to left iliac fossa. Hiccough. Small quantity of clear urine passed; no flatus passed 6.7.16. Enema given; small quantity of fæcal material passed, which was tarry and was evidently changed blood. On same day a small quantity of fæcal material passed through track of missile in back; flatus passed after 7.7.16. Distention much relieved. Patient much more comfortable. Fistula in back still discharging, but a loose motion passed by rectum. Condition excellent. Sent to base	Sent to base
Abdominal pain, tenderness, rigidity, no vomiting, slight distention, no flatus or urine passed. Morphia, water, bismuth 20.7.16. Water and flatus passed. Very comfortable. Sent to base	Sent to base
Compound fracture femur, put up under anæsthetic Third day, vomiting and pain in abdomen, continuing and increasing in severity; tenderness in right iliac fossa. Diagnosis of embolus of mesenteric artery. Patient not fit to operate upon. Died on fifth day. Post-mortem revealed injury of right innominate bone, with adherent gut and complete obstruction	Death
Severe hæmorrhage during transit in ambulance. Died two minutes after admission	Death

OPERATED UPON.

SYMPTOMS AND TREATMENT	PROGRESS	RESULT
2.7.16. Laparotomy left rectus. Missile removed from great omentum; small intestine bruised and distended, and punctured (small) in one place; this was sutured; tube inserted. Pituitrin, eserine and bismuth given	2.7.16. Pulse good, no vomiting, flatus passed 3.7.16. Distention, vomiting, and hiccough 4.7.16. Diarrhœa, less distention. Bismuth and tinct. camph co. 5.7.16. Very marked improvement. Tube removed 6.7.16. Improvement maintained; sent to base	Sent to base
2.7.16. Laparotomy left rectus. Coils of small intestine recently stuck together and surrounded by omentum; these were not touched; turbid sanious fluid mopped out of Douglas's pouch; tube inserted; ether 3 oz. put into peritoneal cavity	Enema given (Salmis) Without enema on 3rd day; good result; passing flatus freely, and comfortable. Sent to base on 3rd day	Sent to base
3.7.16. Laparotomy middle line. Abdomen contained blood; wound found in posterior parietes, and a piece of shrapnel removed from region of splenic flexure; viscera distended and colon bruised; no perforation found; no tube inserted	Enema given for distention. No further vomiting Patient did well, and left for base 2 days later	Sent to base

Continued on next page.

ABDOMINAL WOUNDS

RANK	REGT.	WOUND	OTHER WOUNDS COMPLICATING	MISSILE	TIME ELAPSED
Private	E. Surreys	Penetrating abdomen over liver	Nil	High-explosive shell	20 hours
—	—	Penetrating abdomen	Nil	Shrapnel	20 hours
—	—	Penetrating abdomen	Large wound thigh same side	Bullet	12 hours
Private	Border	Penetrating peritoneum	Both thighs	Shrapnel	36 hours
L.-Corp.	S. Lancs.	Penetrating abdomen, left buttock	Compound fracture innominate bone	High-explosive shell	16 hours
Private	Can.	Extensive wound of rectum	Extensive wounds of buttock and right shoulder; compound fracture of innominate bone	High-explosive shell	16 hours
Private	Can.	Scrotum, perineum, and lower rectum blown away	Compound fracture innominate bone	High-explosive shell	16 hours
Sergeant	R. F. A.	Perforating abdomen, left back	Nil	Shrapnel bullet	18 hours
Private	W. Rid.	Perforating abdomen, left back	Nil	High-explosive shell	15 hours
Private	Can.	Perforating abdomen, left buttock	Compound fracture of left forearm and multiple wounds	High-explosive shell	15 hours
L.-Corp.	W. Rid.	Perforating abdomen, through left chest	Penetrating thorax	High-explosive shell	16 hours

OPERATED UPON—*continued.*

SYMPTOMS AND TREATMENT	PROGRESS	RESULT
Wound excised and laparotomy. Hole in liver, from which a piece of high-explosive shell and clothing were extracted; gas bubbled out; tube inserted; washed out with H_2O_2 and eusol	Sent to base 2 days later doing well	Sent to base
Laparotomy. Small intestine punctured in 7 places; considerable plastic peritonitis. Holes sutured; Douglas's pouch drained; tube inserted; no ether	Collapse and death 36 hours after operation	Death
Large piece of small intestine protruding, perforated in three places. Resection of 3 feet of gut and end-to-end anastomosis performed through the wound. Wound in thigh excised	Progressed favourably for 3 days. Began to vomit at 7 p.m. After a copious vomit died at 8 p.m.	Death
Urethra ruptured, and extravasation of urine into the right thigh; ischium fractured; rectum damaged. Suprapubic cystotomy performed, and a quantity of blood-stained, sweet-smelling urine evacuated. Wound in thigh and perineum very offensive. Bladder drained; catheter passed and tied in. Incision made into thighs. Wound in perineum drained	Death 2 days later from toxæmia	Death
Laparotomy through left rectus. Four large perforations of small intestine and two in the descending colon; root of mesentery traversed. Fæcal extravasation mopped out; holes in gut sutured in two layers and covered with omentum; tubes inserted; no ether left in; piece of high-explosive shell found and removed	Patient did well for two days. Vomiting, however, persisted, but never became obstructive, chiefly biliary. Bowels moved with enema on 4th day. Uncontrollable vomiting persisted despite all attempt to stop it, and patient died on the 7th day after operation. Post-mortem revealed nothing to account for death	Death
Excision of wound in shoulder, and removal of large piece of buttock. Left inguinal colotomy performed; blood escaped from peritoneal cavity	Wound in buttock satisfactory; colotomy working well. Sent to base 5 days later	Sent to base
Excision of wound; salt pack; left inguinal colotomy performed; blood escaped from peritoneal cavity	Wound doing well and colotomy working satisfactorily. Sent to base 5 days later	Sent to base
Laparotomy left rectus. Twelve large perforations of the small gut, and extensive intraperitoneal hæmorrhage. Blood mopped up, with extravasated bowel contents; all holes in the gut sutured in two rows; omentum stitched over gut	Collapse and death 18 hours after operation	Death
Patient died whilst going under anæsthetic	At post-mortem, abdomen full of blood; left common iliac vein and internal iliac artery wounded	Death
Laparotomy middle line. Much hæmorrhage; one large and one small perforation of small gut. Sutured in two rows and covered with omentum; contents mopped out of peritoneal cavity; foreign body found and removed. Old tuberculous glands in mesentery	Sent to base 6 days after operation, doing well	Sent to base
Laparotomy middle line above umbilicus. Two holes high up in anterior wall of stomach. Sutured and covered with omentum; blood and stomach contents mopped up. Old tuberculous glands in mesentery	Did well, and went to base 8 days later	Sent to base

Continued on next page.

ABDOMINAL WOUNDS

RANK	REGT.	WOUND	OTHER WOUNDS COMPLICATING	MISSILE	TIME ELAPSED
Private	Can.	Penetrating abdomen	Penetrating left thorax	High-explosive shell	15 hours
Private	M. G. C.	Penetrating buttock, right	Right leg	Bomb	50 hours
Private	A. I. F.	Penetrating umbilicus	Nil	High-explosive shell	10 hours
Private	A. I. F.	Penetrating chest, diaphragm, spleen, left kidney	Spine; paresis of both legs, distention and overflow of bladder, and rectal incontinence	High-explosive shell	12 hours
Private	A. I. F.	Penetrating left chest, spleen, and lung	A few penetrating wounds of skin on left side	High-explosive shell	14 hours
Private	—	Penetrating right chest behind	Gunshot wound of scalp	Shell	36 hours
L.-Corp.	A. I. F.	Penetrating perineum, very small	Right leg	Bomb	18 hours
Private	A. I. F.	Penetrating right back	Nil	High-explosive shell	18 hours

OPERATED UPON—*continued.*

SYMPTOMS AND TREATMENT	PROGRESS	RESULT
Laparotomy middle line above umbilicus. Blood mopped out. No damage to gut or solid viscus	Went to base 6 days later, doing well	Sent to base
9.7.16. Laparotomy right rectus. Perforation of terminal ileum, with acute kink causing total obstruction; kink no doubt aided by old operation for appendicitis. Single perforation buried and covered with omental graft; ether 3 oz. put into Douglas's pouch. Distention of whole of small intestine.	Vomiting for 2 days. Enema, eserine, pituitrin, bismuth; good result from enema; 3rd day vomiting ceased. Foul discharge from tube which continued to be fæcal from 4th day. Convalescence uneventful 29.7.16. Sent to base well, and taking solid food. News from base, England: Doing well	Sent to base
2.7.16. Wound excised. Hole in peritoneum enlarged. Transverse colon prolapsed and bruised; no perforation of viscus. Gut washed with saline and returned; no tube; wound closed by Mayo's method	Acute bronchitis set in on following day, also loose evacuation of bowels, with mucus. Patient very blue during operation 24.7.16. Pneumonia 25.7.16. Death	Death
3.7.16. Very collapsed from loss of blood. Hole in loin opened up. Spleen not bleeding profusely. Peritoneum stitched, hole in diaphragm stitched; left kidney pulped, nephrectomy performed	Polyuria followed; catheter passed 4-hourly; bowels moved. Patient steadily improved, but difficulty was experienced with back owing to incontinence 28.7.16. Left for base; good pulse, taking food well, urine clear	Sent to base
3.7.16. Peritoneum closed; spleen stitched; wound excised, cleaned, and packed. Large communication with pleura	24.7.16. Still very collapsed; no vomiting; distention still present 25.7.16. Bowels open with enema; general improvement; wound clean; colour better 26.7.16. Improvement maintained; taking solid food 28.7.16. Condition excellent; sent to base	Sent to base
3.7.16. Laparotomy right rectus above umbilicus. Large quantity of bile let out; right kidney pouch full of bile. This was drained by tube through loin coming up to tear in gall-bladder. No other viscus injured	Did well for 2 days; bowels moved, fæces coloured. This man was very emaciated on admission, and had lain out 12 hours in no-man's-land 20.7.16. Diarrhœa set in; no vomiting; sudden collapse in night, and death, 12.30 p.m.	Death
5.7.16. Catheter passed; small quantity of blood-stained fluid withdrawn. Laparotomy middle line below umbilicus. Perforating wound of pelvic colon near junction with rectum. Stitched, and covered with omentum, after mopping out peritoneum and Douglas's pouch, which was full of urine; omental graft stitched over hole in bladder; ether 3 oz. left in; catheter left in; tube inserted to Douglas's pouch	Biliary vomiting persisted; stomach washed out and much bile and mucus washed away; no further vomiting; no distention; urine coming by catheter. Eserine and pituitrin given, and bismuth. 26.7.16. Enema given; good result. All food by mouth stopped for 24 hours 27.7.16. Catheter taken out; urine passed naturally; taking nourishment well; improvement rapid; bowels acting; taking food well 29.7.16. Sent to base. News from base, England: Did well	Sent to base
4.7.16. Laparotomy right rectus. Blood and mucus coming from high up; penetrating wound of hepatic flexure and gall-bladder. Fluid mopped out; omental graft fastened over small opening in flexure; tube inserted to gall-bladder and perforation of gut; ether 3 oz. into peritoneum; pituitrin, eserine, and bismuth given as in all other cases	25.7.16. Distention vomiting (biliary); enema, good result; eserine 26.7.16. Slightly jaundiced; tube twisted, bile followed into dressing 27.7.16. Bowels moving (coloured stools); patient much improved 28.7.16. Condition very satisfactory in every way 29.7.16. Improvement maintained; bowels open; taking food well; sent to base News from base, England: Did well	Sent to base

Continued on next page.

RANK	REGT.	WOUND	OTHER WOUNDS COMPLICATING	MISSILE	TIME ELAPSED
Private	A. I. F.	Penetrating right side	Nil	High-explosive shell	18 hours
Private	A. I. F.	Penetrating right abdomen	Nil	Shrapnel	6 hours
Private	A. I. F.	Penetrating abdomen	Nil	Shrapnel	8 hours
Private	A. I. F.	Penetrating abdomen	Nil	Shrapnel	19 hours
Private	W. Y.	Penetrating chest and abdomen, right side	Thorax	Shrapnel	20 hours
Private	A. I. F.	Penetrating buttock	Nil	High-explosive shell	36 hours
Q.M.-Sgt.	T. M.	Penetrating abdomen from back	Gunshot wound of skull, compound fracture	High-explosive shell	18 hours
Private	A. I. F.	Penetrating abdomen from left side	Left thorax, compound fracture of two ribs	High-explosive shell	50 hours

OPERATED UPON—*continued*

SYMPTOMS AND TREATMENT	PROGRESS	RESULT
24.7.16. Laparotomy right rectus. Perforation (small and single) of ascending colon just above junction with cæcum. Closed by omental graft; tube; ether 3 oz.; pituitrin	25.7.16. Distention vomiting (biliary); enema, good result; eserine 26.7.16. Bowels moved; no further vomiting; taking fluids 27.7.16. Great improvement, taking nourishment; bowels moving 29.7.16. Improvement maintained; sent to base News from base, England: Did well	Sent to base
26.7.16. Laparotomy right rectus. Wound excised. Penetration of duodenum and small intestine (small hole); peritoneum full of liquid contents of small intestine. Mopped out with gauze; holes stitched up; omental graft; one tube to duodenum, one to Douglas's pouch; ether introduced	27.7.16. Satisfactory; no vomiting 28.7.16. Bowels moved; fluids taken 29.7.16. Very improved 30.7.16. Very improved 31.7.16. Very improved; tube shortened; still in hospital 1.8.16. Very improved 2.8.16. Very improved; sent to base	Sent to base
26.7.16. Laparotomy right rectus. Peritoneum full of green mucous material. Mopped out. Six large perforations of small intestine and one in transverse colon. Buried by two rows of Lembert stitches; one large tube to Douglas's pouch and one to right kidney pouch; ether introduced into peritoneum	27.7.16. Biliary vomiting; stomach washed out 28.7.16. Bowels moved with enema; taking fluids; respiration rapid 29.7.16. Steady improvement apart from chest 31.7.16. Improvement maintained; still in casualty clearing station 4.8.16. Improvement maintained; sent to base	Sent to base
28.7.16. Laparotomy right rectus. Right kidney pouch containing clotted blood; furrowed wound of liver. Packed with gauze; no tube	29.7.16. Some vomiting; otherwise satisfactory 30.7.16. Bowels open; no further vomiting; plugging loosened 31.7.16. Very satisfactory; plugging removed under gas; still in casualty clearing station 2.8.16. Very satisfactory; sent to base	Sent to base
28.7.16. Laparotomy right rectus. Peritoneal cavity full of blood. Mopped out. Bullet traversed meso-appendix and wounded ileum. Wound sutured; bleeding point picked up behind peritoneum and twisted off; ether inserted; also tube to Douglas's pouch	29.7.16. Satisfactory; slight vomiting; evening temperature 102°, respiration and pulse rapid 30.7.16. Diarrhœa; chest symptoms more pronounced; no further vomiting; taking liquid nourishment well; temperature 103°; pulse failing 31.7.16. Died 10 a.m.; bowels incontinent; chest condition extreme	Death
3.7.16. Missile entered pelvis, opening both bladder and rectum; fæcal discharge from wound; infection and gas gangrene spreading into left thigh and calf of leg. Colotomy, left inguinal, performed; tube inserted into wound; incisions into thigh; anti-gas vaccine given	28.7.16. Condition spreading into thigh 29.7.16. Colotomy opened, lower limb washed through three times daily 30.7.16. Colotomy working well, lower limb washed through clean; patient very toxic from thigh; died 7.30 p.m.	Death
3.7.16. Laparotomy right rectus. Hole just behind and external to cæcum; cæcum bruised but not perforated; blood free in Douglas's pouch. Mopped out; hole in posterior peritoneum closed; tube inserted to pouch; omentum brought down; ether injected. Wound in skull excised	29.7.16. Very satisfactory 30.7.16. Very satisfactory	Sent to base
0.7.16. Laparotomy. After preliminary washing out of stomach, wound found about size of a florin 3 feet from duodenum in jejunum, adherent to parietes; extreme distention of gut above wound, and collapse below; patient's condition critical. Jejunostomy performed	Collapse and death, associated with tetany of a mild form 7 hours after operation	Death

Continued on next page.

ABDOMINAL WOUNDS

RANK	REGT.	WOUND	OTHER WOUNDS COMPLICATING	MISSILE	TIME ELAPSED
Private	A. I. F.	Penetrating right iliac region	Nil	High-explosive shell	12 hours
Private	A. I. F.	Penetrating scrotum	Both thighs, left arm, hand, and neck	High-explosive shell	About 15 hours
Sergeant	A. I. F.	Penetrating left side, emerging epigastrium	Nil	Shrapnel	Wounded night of 4.8.16, operation a.m. 6.8.16
Corporal	R. E.	Penetrating abdomen just below umbilicus	Left thigh, left forearm	High-explosive shell	20 hours
Private	A. I. F.	Penetrating left abdomen	Left thigh, right chest	High-explosive shell	36 hours
Private	162	Penetrating left back of abdomen	Head, right leg	High-explosive shell	36 hours
Private	A. I. F.	Penetrating abdomen from left back	Nil	Shrapnel	36 hours
Private	A. I. F.	Penetrating abdomen left back	Nil	High-explosive shell	16 hours

OPERATED UPON—*continued.*

SYMPTOMS AND TREATMENT	PROGRESS	RESULT
3.8.16. Rigidity on right side; persistent biliary vomiting; neither flatus nor urine passed; fullness in Douglas's pouch; dullness right iliac fossa; liver dullness partially obliterated. Excision of wound to peritoneum; abdomen opened through right rectus; escape of large quantity of bowel contents; large piece of high-explosive shell removed from pelvis; two ragged perforations of small intestine sutured and grafted with omentum; tube to Douglas's pouch; ether 3 oz. inserted; one small tube to wound in intestine. Pituitrin, eserine, bismuth, water	4.8.16. Biliary vomiting; stomach lavage; enema, copious result after removing some fæces with finger; comfortable; pulse 96, temperature 100°. Wound dressed, clean; both tubes discharging 5.8.16. Comfortable; offensive discharge 6.8.16. Wound swollen; offensive discharge from tubes; some gas in abdominal wall 7.8.16. Fæcal discharge from wound; tube left out; abdominal wall slacker; bowel moving 9.8.16. Much improved; discharge from fistula less; sent to base	Sent to base
3.8.16. Great pain in penis; abdominal walls very rigid. Peritoneum full of urine; catheter specimen blood-stained. Urine mopped out; omentum taken to hole in bladder and fixed; catheter tied in; other wounds cleaned and dressed; tube to Douglas's pouch	6.8.16. Comfortable; catheter removed 7.8.16. Bowels moved with enema; passing water per urethram 9.8.16. Improvement maintained; no further complications; sent to base	Sent to base
6.8.16. Prolapse of transverse colon and omentum. One small wound in transverse colon closed and omentum sewn over it. Large piece of left rectus and sheath blown away. Wound excised and brought together with chrome gut and silkworm gut; tubes inserted	7.8.16. Wound clean; vomiting of anæsthetic type 8.8.16. Stomach lavage; vomiting less; pulse 80, respirations 20 9.8.16. Great improvement; sent to base	Sent to base
4.8.16. Large piece of high-explosive shell weighing about 4 oz. removed from pelvis; contusion of small intestine and omentum; blood in pouch of Douglas. Missile removed; tube inserted to Douglas's pouch; omentum pulled down over contused intestine	5.8.16. Vomiting, otherwise well 6.8.16. Vomiting less, and more comfortable 7.8.16. Vomiting ceased; aperient given 8.8.16. Improvement maintained; no further complications	Sent to base
6.8.16. Laparotomy. Peritoneal cavity full of blood; wound of pancreas, lesser sac, and liver. Missile under skin removed; blood cleaned out; two bleeding points ligatured; liver packed; tube into right kidney pouch	7.8.16. Collapse and death in early morning	Death
5.8.16. Laparotomy. Perforation of descending colon; serous coat torn through in another place; escape of bowel contents. Wound in colon sutured and covered with omentum; contents mopped out of pelvis; tube inserted to pelvis. Large retro-peritoneal hæmatoma	6.8.16. Comfortable, but rather restless 7.8.16. Rapid gas gangrene of whole of abdominal wall; death at 2 p.m.	Death
5.8.16. Laparotomy. Shrapnel bullet found in mesentery; much extravasation; large perforation of hepatic flexure, with escape of liquid fæces. Mopped out; omentum stitched to hole in intestine; tube inserted to wound and also to pelvis; ether 3 oz. injected. Patient very collapsed. Saline given during operation	6.8.16. Very offensive discharge from tubes; respiration and pulse very rapid; very restless, and getting out of bed; no vomiting 7.8.16. Collapse and death 40 hours after operation	Death
5.8.16. Laparotomy. Blood in peritoneal cavity; large hæmatoma along whole length of descending colon. Blood mopped out of peritoneum and Douglas's pouch; wound closed; drainage from wound in back	6.8.16. Comfortable; no vomiting 7.8.16. Complaining of pains in wound; aperient given; stitches removed; wound septic, discharging pus 8.8.16. Distention relieved by pituitrin and enema; much improved; wound cleaning well 9.8.16. Improvement maintained	Sent to base

Continued on next page.

ABDOMINAL WOUNDS

RANK	REGT.	WOUND	OTHER WOUNDS COMPLICATING	MISSILE	TIME ELAPSED
Private	A. I. F.	Penetrating abdomen right side	Nil	High-explosive shell	16 hours
Private	—	Fracture of left leg, compound. Penetrating abdomen to right of umbilicus in iliac fossa	Fracture of left leg	High-explosive shell	30 hours
Private	—	Perforated abdomen right back	Nil	High-explosive shell	30 hours
Private	A. I. F.	Perforated abdomen right back	Nil	High-explosive shell	27 hours
Private	R. Essex	Perforated abdomen right back	Compound depressed fracture of skull in occipital region	Shrapnel	22 hours
Private	—	Penetrating back to abdomen	Penetrating thorax	High-explosive shell	19 hours
Private	A. I. F.	Penetrating abdomen left below umbilicus	—	High-explosive shell	16 hours

OPERATED UPON—*continued.*

Symptoms and Treatment	Progress	Result
5.8.16. Laparotomy. Perforation of ascending colon, single, with extravasation. Wound stitched; omentum brought over; tube inserted; ether 3 oz. left in tube	6.8.16. Comfortable; no vomiting 7.8.16. Enema given; good result 9.8.16. Bowels moving; patient satisfactory	Sent to base
6.8.16. Laparotomy. Small intestine perforated in three places. Sutured, and omentum stitched over; piece of high-explosive shell removed from pelvis. Extensive extravasation of bowel contents. Mopped up; tube to Douglas's pouch; ether 3 oz. put in. Leg swollen. Dressed and put up in splint	7.8.16. Very rapid gas gangrene of leg, and death	Death
6.8.16. Laparotomy. Perforation of cæcum in two places; omentum wounded and bleeding. Contents mopped out; holes in cæcum stitched and covered with omentum; tube in Douglas's pouch and to wound; ether 3 oz. given into peritoneum	7.8.16. Patient well; no vomiting 8.8.16. Patient well 9.8.16. Bowels moved; no vomiting	Sent to base
10.8.16. Laparotomy through right rectus. Perforated posterior abdominal wall just above cæcum and to outer side of ascending colon; peritoneal cavity, right side, full of blood; contusion of ascending colon, with hæmorrhage into its walls; large retroperitoneal hæmatoma. Blood mopped out; tube inserted to perforation in peritoneum; omentum pulled down over it. Blood in peritoneum extremely offensive. No ether left in peritoneum	11.8.16. Wound very offensive and discoloured; all stitches removed and a large portion of rectus cut away; saline 4 pints with brandy given through day; *blood of a very offensive nature passed by bowel* 18.8.16. Spread of gangrene in wound; death at 4 p.m. Bowels moved before death	Death
17.8.16. Laparotomy through right rectus. Perforated posterior abdominal wall to outer side of ascending colon; peritoneum full of blood; ascending colon contused and blood in its walls. Tube put down to wound in posterior wall; shrapnel bullet removed; wound closed with through-and-through silkworm gut; no ether left in peritoneum. Skull wound trephined; blood-clot evacuated from brain; wound syringed out; some brain matter coming away. Head operation performed simultaneously by Capt. Hay	Vomiting for 4 days after operation; pituitrin, eserine, bismuth, and soda bicarbonate given Flatus passed after enema on 2nd day after operation; abdominal wound septic; stitches removed Bowels moved normally on 4th day, with some changed and offensive blood; twitchings of face and limbs developed on this day; abdominal wound cleaning up satisfactorily 21.8.16. Squint and twitchings; abdominal wound cleaning well 22.8.16. Bowels moved; taking nourishment; twitchings worse; abdominal wall clean 24.8.16. Convulsive movements marked; squint very pronounced; patient unconscious; death	Death
19.7.16. Laparotomy through right rectus. Duodenum perforated in descending part. Piece of omentum taken and grafted over opening; tube inserted	Difficult respiration for 2 days; temperature reaching 100°. This slowly settled. Six days later taking custard; bowels moving normally; no vomiting. Sent to base 8 days after operation	Sent to base
26.8.16. Rigidity; vomiting; no flatus; no urine; rigidity most on left side abdomen. Laparotomy middle line infra-umbilically. Perforated posterior peritoneum; blood in Douglas's pouch; contusion of wall of descending colon; foreign body found and removed. Tube to hole in peritoneum and through wound of entry; wound of entry excised; buttock wound laid open, drained; salt pack. Intratracheal ether	Uncomplicated convalescence 1.9.16. Left for base	Sent to base

A NOTE ON A SERIES OF CASES OF GUNSHOT WOUNDS OF THE ABDOMEN.

By Lieutenant-Colonel SEYMOUR BARLING, R.A.M.C. (T.)

The cases on which this paper is based were for the most part treated at one of the advanced operating units established for the reception of serious cases, especially those of the abdomen and thorax; these advanced hospitals lie between the field ambulances and the casualty clearing stations. The cases, therefore, are selected to some extent, the more serious alone being received at such stations; on the other hand, many cases arrive at hospital in a moribund condition, and such are unfit for operation, and are not included in the figures given. The exact proportion of the moribund cases to those deemed fit for operation is difficult to determine—it varies from time to time, owing to altered conditions of fighting, and during periods of stress in operating it is impossible to keep records of these cases. Every case in which operation held out the slightest hope was included, however; hence the death-rate is necessarily high, as the condition of a large number of the patients was desperate, and the operations are generally long, and are such as even in an uninjured patient would of themselves inflict much shock.

All cases but one in the series were operated on within twenty-four hours of being wounded, and a few cases as early as four hours after; the delay, short as it is, is undesirable; but as it occurs generally between the advanced dressing station and the place where the casualty occurs, it seems unavoidable, owing to the difficulty of removing such patients under fire unless conditions are exceptionally favourable.

On reaching hospital, the patient is taken to a reception ward, the stretcher is placed on a bed, and the patient given plenty of blankets and hot-water bottles, and hot water in sips. All clothes are then cut off with the least possible disturbance, and the stretcher is replaced by a clean one. In most cases the sooner the patient is taken to the operating theatre the better. In a few, however, where shock is intense, a delay of an hour or two seems beneficial, and operation becomes practicable in cases which at first seemed hopeless. Operation usually shows that hæmorrhage has temporarily ceased, and intestinal leakage is but rarely present. Under these circumstances a short delay to permit of recovery from the effects of the journey seems desirable. In these cases, too, death after operation occurs from shock far more frequently than from peritonitis.

Diagnosis.—In spite of the fact that the majority of the patients are well under the influence of morphia, which obscures some of the symptoms, diagnosis is usually not difficult. Intense pallor and collapse, with feeble pulse, accompanied by a bullet wound somewhere in the lower thoracic, abdominal, or pelvic zones, and some localizing abdominal symptom such as pain, tenderness, or rigidity, form the usual picture.

In some cases extrusion of the abdominal viscera, or severe laceration of the parietes down to or opening the peritoneal cavity, makes laparotomy imperative ; in others the path of the missile can be presumed from the position of the entrance and exit wounds—if this crosses any corner of the peritoneal cavity, visceral injury is probable. Penetrating wounds of the lower thoracic region or of ne buttocks offer greater difficulties. In the former, the pleural and peritoneal cavities are often both opened and the diaphragm perforated. Upper abdominal pain, tenderness, or rigidity may be present independently of damage to abdominal viscera ; but the presence of dullness in the flanks, vomiting, or extreme pallor, in the absence of a hæmothorax, suggests the necessity of a laparotomy. Wounds of the buttock and upper third of the thigh should always be regarded with suspicion. Some are merely local. Some penetrate the pelvis but remain extraperitoneal, giving rise to trouble at a later date owing to infective processes. Others penetrate the abdomen and may injure any viscus there ; such cases will usually exhibit some localizing condition in the abdomen, such as tenderness, which, taken in conjunction with the situation of the wound, should lead to an exploration ; a specimen of urine should always be obtained if possible, the bladder being one of the viscera most frequently damaged with these wounds.

The commonest localizing abdominal symptoms are tenderness, rigidity—which may be local or general—patchy dullness—often movable—and vomiting. Several pints of blood, however, may be free in the peritoneal cavity without giving rise to dullness ; and all the other symptoms may be present with a wound of the parietes only, especially if a foreign body is lying in the abdominal wall.

Many cases of wounds of the parietes alone are sent to hospital as penetrating wounds, and need careful watching. In such cases the general state of the patient is as a rule much better than it would be had penetration occurred. Local symptoms of rigidity and tenderness are, however, often present, especially if the missile lies in the abdominal wall or if the peritoneum is bruised or encroached upon. Vomiting and dullness are rarely present. Rigidity is so marked in some of these cases as to be very misleading ; it will be found, however, that if the patient is propped up and the knees are raised so as to relax the abdominal muscles, the rigidity will soon disappear to a large extent if no visceral injury is present.

As in other parts of the body, the zone of damaged tissue extends to a varying distance in all directions around the path of the missile ; wounds of the parietes may therefore tear or severely contuse the viscera without penetration. These cases are particularly dangerous, and may be fatal, as in the following instance, in which the true significance of a wound in the back was unfortunately missed.

Case 1.—**Rupture of the small intestine without perforation of the peritoneal cavity.**

Lieut. S. was admitted to hospital twelve hours after being shot across the back in the lower dorsal region ; the entrance wound was one inch to the right of the middle line ; thence the bullet had passed across into the erector spinæ and lumbar muscles of the other side ; the exit wound was large, deep, and 'explosive' in character. On admission, patient was under morphia. Pulse 108, and general condition good. No vomiting. He was watched a few hours, the pulse falling in this interval to 92.

He now complained of abdominal pain, and became a little collapsed—no localizing tenderness or rigidity was present in the abdomen. He was taken to the theatre and the posterior wound thoroughly examined. Though deep on the left side, it was seen that the wound had not penetrated the abdominal cavity, a thickness of at least a quarter of an inch separating the bottom of the wound from the peritoneum of the posterior belly wall. The patient collapsed quickly after return to the ward. A general peritonitis secondary to a ruptured loop of small intestine was present. There was no perforation of the peritoneal cavity, but only a thin layer of tissue separated the bottom of the wound from the peritoneum.

The Anæsthetic.—Cases of this nature would seem theoretically most suitable for spinal anæsthesia, with its tendency to produce the minimum amount of shock and diminish the possibility of chest complications. Stovaine was used in some half a dozen cases; in all it produced the most intense collapse, and in one case under the care of a colleague it was undoubtedly the cause of death. Its use was therefore discontinued, and general anæsthesia—commencing with chloroform, and passing on to warm ether given by the Shipway apparatus—was found most satisfactory. Chest complications were singularly absent, except in cases accompanied by some contusion or wound of the thorax.

Operation.—A free median incision usually gives the best approach. On opening the abdomen, the two striking things usually observable are an enormous quantity of blood filling all parts of the belly, and the absence of leakage from the small intestine. The small intestine is injured far more frequently than any other viscus, and is found collapsed and absolutely still; the absence of leakage of intestinal contents is in striking contrast to that which occurs in cases of rupture of the bowel met with in civil life.

Rapidity in operating is very desirable, and it is best to proceed on some definite plan. The blood having been sponged out from all parts, bleeding points in mesentery and omentum are picked up as they present. Then, commencing at the ileocæcal valve, the whole small intestine and mesentery is examined from below upwards. Perforations are marked by some method, as by attaching clamps temporarily, whilst the examination is continued; usually perforations will occur in groups here and there in the bowel. The colon is next examined in the same manner, again commencing at the ileocæcal valve. Unfortunately, leakage from the large bowel is much more likely to occur than from the small intestine, and a fæcal odour is not uncommonly present and detectable when the peritoneal cavity is opened in such cases. Routine examination of the whole of the large and small bowel and their mesenteries must be carried out in all cases, whatever part of the abdomen is perforated. Further investigations, whether of the pelvic, lumbar, or subdiaphragmatic zones, will be determined by the site of the injury or the track of the missile. In most cases the damage to the viscera is quickly discovered by routine examination; but in some—especially when the upper or lower part of the abdominal cavity is involved—perforations and bleeding vessels may be easily missed.

Case 2.—**Perforation of the posterior surface of the stomach.**

Pte. W. H. was admitted to hospital five hours after being wounded; he was very pale and collapsed, pulse 80, vomiting was profuse, and the vomit contained blood. He had one small wound an inch to the left of the umbilicus; the abdomen

was dull in the flanks, and generally rigid and tender. Much blood was found on opening the abdomen; examination showed a few bleeding points in the omentum, and one area where the bowel was contused; the stomach appeared normal, but further examination expressed a large amount of blood-clot from the foramen of Winslow, and on tearing through the great omentum and opening the lesser sac, this cavity was found to contain a mass of blood-clot which came from the margins of a perforation in the posterior surface of the stomach. This was sutured across the lesser sac. No exit wound from the stomach could be found. The patient made a good recovery.

Case 3.—**Wound of the cæcum and appendix and extraperitoneal wound of the bladder.**

Pte. C. was admitted to hospital ten hours after being wounded in the left gluteal fold. He was pale and restless, pulse 112, abdomen very rigid and dull in the flanks. At operation there was much blood in the peritoneal cavity; the appendix was wounded in two places and was excised; there was a hole in the cæcum, which was sutured; severe bleeding had occurred from a vessel in the mesocolon; the bladder appeared normal. Gas gangrene had already commenced around the gluteal wound. At the end of twenty-four hours the patient had rallied well, but urine commenced to flow from the drainage tube in the buttock; none was passed per urethram. The patient died on the third day. No obvious cause for death was present; the peritoneal cavity was clean, and though there were two extraperitoneal wounds on the anterior surface of the bladder, the urinary drainage through the buttock wound appeared to be satisfactory.

Whilst perforations are usually easily found, bruising of the bowel, such as may afterwards cause a slough which will eventually give way, may be missed; such places should be looked for when examining the gut, and treated by invagination by purse-string suture. Many of the perforations of the bowel may be closed in the ordinary way by purse-string suture or Lembert stitch, but widespread damage to the mesentery, or the occurrence of extensive or numerous perforations close together, calls for resection. At first the method of lateral anastomosis was used, but afterwards end-to-end anastomosis by Connell suture, reinforced by Lembert stitches, proved quicker and more efficient. In none of the cases in which end-to-end anastomosis was performed was this procedure followed by paralytic distention of the gut as recorded by Richards and Fraser.* The following case suggests that this paralysis of the bowel may be due to the original trauma rather than to the particular method employed in repairing the damaged viscus.

Case 4,—**Large lacerated wound of the left loin.**

Sergt. A. was admitted to hospital nine and a half hours after being wounded. His general condition was fair, but the abdomen was distended and tender. Laparotomy showed enormous distention of colon and stomach, so that before the abdomen could be properly examined a trocar had to be introduced into these viscera to release the gas. It was then found that the projectile had not penetrated the peritoneal cavity, but had gone down to the outer surface of the peritoneum and stripped all the tissues off this surface for four or five square inches. The patient recovered, but suffered for several days after operation from vomiting and distention.

The mortality of the cases in which resection was performed was very great, and it seems advisable to avoid it wherever suture is possible, even

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* "Paralysis of the Intestine after Resection for Gunshot Injuries," by Captain Owen Richards and Captain John Fraser, *British Medical Journal*, July 1, 1916.

though the latter produces great narrowing of the lumen of the gut; observation shows that what appears to be extreme narrowing at operation becomes much less obvious in a few days as the bowel recovers its function.

The following case illustrates the very considerable damage that may be done to the small bowel and mesentery without death occurring, provided the patient is within reach of early operative treatment.

Case 5.—**Bullet wound of the abdomen.**

Lieut. G. was wounded by a bullet which entered the abdomen three inches to the left of and just below the umbilicus. He was admitted seven hours after being wounded, his condition being fairly good; pulse 112; no vomiting; abdomen dull over the right half and above the pelvic brim, but not tender or rigid. On opening the abdomen there was an enormous quantity of blood in the peritoneal cavity. The mesentery of the lower part of the ileum was torn extensively, and the bowel itself cut across completely, five feet from the ileocæcal valve. There were also several other perforations in the bowel in this segment. The last five feet of the ileum were therefore resected, and end-to-end junction performed two inches from the ileocæcal valve. Four other perforations in the upper part of the small intestine were closed by suture, and the abdominal wall was sewn up in one layer without drainage. The patient made a good recovery, but had diarrhœa for some weeks afterwards. When heard from recently, he was walking about and able to take all foods but fruit without inconvenience.

The great blood loss that occurs in most of these cases calls for the administration of saline, and at operation two pints were usually given, either intravenously if assistance was available, or from a Lane's bag into the axillæ if short-handed. Cases in which severe shock was already established seemed to derive very little benefit from this, for though the pulse picked up for an hour or two, it rapidly fell away, the patient meanwhile sweating profusely, thus seeming to illustrate the uselessness of putting more fluid into the circulation. The less severely shocked cases, however, undoubtedly derived great benefit from this measure, and also from saline given per rectum after operation.

WOUNDS OF SPECIAL ORGANS.

Small Intestine.—In 45 successive laparotomies the small bowel was injured in 25 cases (56 per cent): in 14 of these it was the only viscus injured, and in 11 cases other viscera were wounded as well. Resection and anastomosis was performed in 12 cases: in 10 of these a single resection was done (3 recovered and 7 died; in 6 of the latter other viscera were also wounded); 2 cases needed a double resection (both died).

Stomach.—This was perforated in 3 cases; 2 recovered and 1 died; in 2 of the cases the small bowel was wounded as well. Vomiting seemed more profuse in cases of injury to the stomach than in injury to other viscera, and in one case severe hæmatemesis was present. In another case in which there was a penetrating wound of the thorax with extensive damage to the right lung, the patient presented signs of abdominal injury, and on exploration a very large quantity of blood was found in the belly; no visceral injury could be found, nor could any source of the hæmorrhage be discovered, and it was presumed that it must have come from the lung and drained down into the abdomen. Later the coronary artery was found cut across close to its origin.

In another patient not operated upon, a perforated stomach and wounded spleen had herniated through the diaphragm into the chest; the symptoms were thoracic rather than abdominal, and no indications for laparotomy were present.

The Colon.—The colon was perforated in 8 cases; 1 recovered and 7 died. The patient that recovered had a wound of the bladder in addition. In 5 of the 7 fatal cases the small bowel was wounded as well as the colon. Leakage of bowel contents seems to occur readily when the large intestine is wounded, and a fæcal odour is frequently noticeable when the abdomen is first opened. Colotomy may be performed with advantage when the patient is very shocked and the hole in the bowel unsuitable for suture.

Bladder.—There were 6 cases of bladder wounds in the series; 2 patients recovered and 4 died. In 5 of the 6 cases the colon or small bowel was injured, and in the sixth the patient died of a pneumonia secondary to a shell wound of the chest. Two of the cases had extraperitoneal wounds only; one recovered after drainage of the retropubic space, the hole in the bladder quickly closing without further operation; this patient also had a left inguinal colotomy performed for a wound of the pelvic colon; in the second case (*Case* 3 quoted above), the wounds of the bladder were not found at operation, but drained effectively through the wound of entrance in the buttock. All cases of intraperitoneal injury had large lacerations, which were treated by suprapubic drainage.

Solid Viscera.—Wounds of the solid viscera were present as follows in 6 out of the 45 cases operated on: liver 2, kidney 1, spleen and kidney 1, liver and kidney 1, small intestine and kidney 1; all these patients died. In two other cases not operated on, the kidney was presumably wounded; both of these recovered. All these cases of wounds of the solid viscera were severely shocked on admission, a condition which rapidly deepened after operation. Speaking generally, the patients were much worse than might have been expected from the local injury found at operation; but it must be remembered that only selected bad cases were sent to the hospital where these cases were treated, and this helps to explain the disappointingly high mortality in wounds of the solid viscera.

The majority of the laparotomies were sewn up by through-and-through silkworm-gut suture without drainage. Cases of injury to the colon, however, were drained both down to the wound and to the bottom of the pelvis. The wounds generally suppurated to a slight extent, either from infection of the edges during manipulations of the perforated bowel, or from the original wound; in no case, however, did any untoward event result from this.

Shock and peritoneal infection were the two principal causes of death, the former greatly predominating; the patient either died within the first few hours after operation without picking up, or, after rallying somewhat for twenty-four or thirty-six hours, secondary collapse set in and death occurred on the second day, the post-mortem failing to show any local cause of death. The cases dying of peritonitis usually presented a typical picture of infection twenty-four hours after operation. Three cases died from pneumonia; in two of these severe injuries of the chest were present.

SUMMARY OF CASES.

Total number of cases (excluding those moribund on admission), 51; no operation, 6; laparotomy performed, 45.

Of the cases not operated on, 2 suffering from wounds of the kidney recovered. The other 4 died: two of these were admitted fifty-two and fifty-seven hours respectively after being wounded, and both had fæcal fistulæ; another case had a diaphragmatic hernia, with wound of stomach and spleen; and the fourth was *Case* 1 quoted above, with a gunshot wound of the back.

The results of the cases operated on are shown in the following table:—

TABLE SHOWING THE RESULTS IN 45 CASES WHERE LAPAROTOMY WAS PERFORMED.

VISCUS INJURED	NO. OF CASES	RECOVERIES	DEATHS
Small intestine only	14	8	6
,, ,, and colon ..	5	0	5
,, ,, ,, kidney ..	1	0	1
,, ,, ,, bladder ..	3	1	2
,, ,, ,, stomach ..	2	1	1
,, ,, ,, liver ..	1	0	1
Stomach	1	1	0
Colon	1	0	1
Bladder	1	0	1
Colon and bladder	2	1	1
Liver	1	0	1
Kidney	1	0	1
Spleen and kidney	1	0	1
Liver and kidney	1	0	1
Intraperitoneal injury without perforation of hollow or solid viscera	10	9	1
Totals ..	45	21	24

Causes of Death.—Shock, 18; peritonitis, 3; pneumonia, 3.

REVIEWS AND NOTICES OF BOOKS.

The Catarrhal and Suppurative Diseases of the Accessory Sinuses of the Nose. By Ross Hall Skillern, M.D. Large 8vo. Second Edition. Pp. xxii+417, with 287 illustrations. Philadelphia and London: J. B. Lippincott Co. 21s. net.

A monograph devoted to a relatively restricted area in the field of rhinology can only be justified by an author's experience of the subject being such as will enable him either to review with ripe judgement contemporary practice in the speciality, or to add something original and of value to the common stock of knowledge of his specialist *confrères*, and Dr. Skillern has amply fulfilled both conditions in producing this work, which has so speedily required a second edition.

The first hundred pages are devoted to general considerations, such as diagnostic examination, the anatomy and development of the various sinuses, general etiology, pathological changes in the mucous membrane, complications, general symptoms, and general treatment. We think the best section in this part is that devoted to the clinical anatomy of the sinuses, which is singularly complete, and with its numerous and excellent illustrations, forms an unusually comprehensive exposition both of the normal anatomy and of the very numerous abnormalities which form an essential aspect of the subject for anyone who is called upon to treat diseases of the nose. The short paragraph on latent empyema of a sinus hardly does justice to the subject of 'latency,' and it scarcely suffices to state that "this condition is in reality a mild catarrhal process which nevertheless may become virulent." The very short section in this part on complications in relation to the orbital cavity and optic nerve, leads one to turn for fuller information to other parts in the volume, particularly that devoted to the sphenoidal sinus, only to be disappointed with the inadequate treatment of these important complications. The relation of polypus formation to suppuration, too, is not so fully considered as we should have expected; and the references to published work on this particular subject suggest that some of the most scientific researches have escaped the author's notice.

The remainder of the volume is devoted to the different sinuses: Part II, the maxillary sinus; Part III, the frontal sinus; Part IV, the ethmoid labyrinth; Part V, the sphenoidal sinus; Part VI, combined empyema or multiple sinusitis.

The part dealing with suppuration in the maxillary sinus not only shows that the author is familiar with practically all the usual operative measures, their advantages, and their several weaknesses, but that he has himself improved on the technique. The methods of other operators he describes and illustrates, and criticizes with good judgement; finally advancing his own preturbinal method, which has much to recommend its more general adoption. He is equally instructive on the question of the radical maxillary antral operation, and here, too, we find he offers useful advice, and suggests valuable improvements in details not generally known to rhinologists. He thoroughly discusses most of the diagnostic methods in vogue; but we wonder why he omits all reference to the one method which yields the most conclusive evidence as to the presence of infective discharges in the antrum, viz., *the suction syringe*, contenting himself with lavage by means of either the Lichtwitz cannula or lavage through the middle meatus, methods which are trustworthy only in cases where the antrum contains more than a small amount of secretion.

The same principle applies to the diagnosis of sphenoidal sinus suppuration, where suction of the contents by means of an introduced cannula affords a clinching diagnostic method when all other means may fail. Nevertheless the section on sphenoidal sinus suppuration is exceedingly good, and the author supplies, what we

have never before seen in any text-book, a good description and a coloured illustration of a cannula in the sphenoidal sinus ostium as seen by the nasopharyngoscope. The remaining sections on the frontal sinus and ethmoid labyrinth deserve very high praise; they are not only up-to-date, but far in advance of most treatises on these subjects.

The printing is clear, and the illustrations are singularly apt and well executed. Copious references are given throughout the text, well representative, especially of American rhinology, but we think not quite so generous to British workers in the speciality as to German writers.

The author has aimed at supplying his medical colleagues with a complete exposition of a relatively new field of special practice—a field in which the science of rhinology is constantly advancing, and therefore continually undergoing changes in views and practice; and if here and there we have ventured to criticize and to note some omissions which appear to us regrettable, it is largely because this work, a monument of industry and research, and reflecting the greatest credit on the writer, is so valuable and complete as a whole that it seems to challenge one to look for them.

Surgical Contributions from 1881 to 1916. By RUTHERFORD MORISON, F.R.C.S., Consulting Surgeon, Royal Victoria Infirmary, Newcastle-on-Tyne. In two volumes. Vol I, General Surgery, pp. 427, figs. 83; Vol. II, Abdominal Surgery, pp. 953, figs. 113. 1916. Bristol: John Wright & Sons Ltd. Vol. I, 15s. net; Vol. II, 30s. net; the two volumes, 42s. net.

THESE collected writings of Rutherford Morison are of great interest for various reasons. In the first place they afford a mine of valuable information, which is made readily accessible by the classification of the papers and by the index. Secondly, they epitomize in an individual manner the surgical progress of nearly thirty years, that is to say, of the modern generation. And thirdly, Mr. Morison has added footnotes in which he criticizes, to-day, his work and views of yesterday. We find these notes in themselves most valuable.

It is noteworthy that Morison's writings in the decade 1880 to 1890 only fill 48 pages, from 1890 to 1900, 416, and from 1900 to 1910, 563. This shows that the author has continued to give out in teaching and writing what he has himself learned from his own practice and experience, and that he has not yielded to the common temptation to allow a press of work and prosperity to prevent publication.

There are, perhaps, two aspects in which these papers are particularly instructive—first, in the different stages they present of the history of the use of antiseptics and the technique of wound treatment; and second, in dealing with modern abdominal surgery from almost its very inception. We can trace, for example, stage by stage, the present-day practice in appendicitis—from the time when it was a new, rare, or doubtful mystery, through the period when acute cases were selected for operation, to the present, when all cases are operated upon as soon as diagnosis is made.

It is impossible to attempt to review or even to epitomize the contents of these volumes, but one cannot refrain from expressing great admiration for the energy and enthusiasm of which they are the outcome.

Diagnosis and Treatment of Surgical Diseases of the Spinal Cord and its Membranes. By CHARLES A. ELSBERG, M.D., F.A.C.S., Professor of Clinical Surgery at New York University. Pp. 330, with 153 illustrations, 3 in colours. 1916. Philadelphia and London: W. B. Saunders Co. 21s. net.

THIS new and original work is divided into three parts, the first dealing with anatomy and physiology, the second with operations and operative technique, and the third with surgical diseases and their treatment. Its leading characteristics are simplicity and clearness. Pictures, radiograms, and text, all conduce to these ends. In the first part, the figures of the anatomy of the nerve roots and the denticulate ligament,

the diagrams of the tracts in the spinal cord, and the radiograms of different conditions of the spine, deserve special notice.

In the section on surgical operations, it is remarkable that a saw is neither mentioned nor figured, all the bone removal being done by cutting forceps. We think that in this and other points the author might have included some reference to other methods which are in common use besides his own—for example, the advantages of making the skin incision of a laminectomy curved to one side, so as not to lie directly over the deep wound. The operations of division of the posterior nerve roots for various conditions, and that of the anterolateral tracts for the cure of pain, are well described, but we are disappointed at finding so little guidance of a critical character as to the scope and prospects of these procedures.

In the section on special diseases and injuries, the author takes a wise and conservative view in regard to the scope of laminectomy for fracture dislocation and for bullet wounds. He holds that when there is evidence of total transverse lesion in these cases, operation does no good, but tends to discredit surgical intervention. The chapters on tumour of the cord are the most valuable in the book. Probably no one has been able to publish such brilliant results in this field of surgical enterprise as Elsberg, with his method of allowing intramedullary tumours to extrude themselves. Leaving removal to a subsequent operation is a very great advance in our knowledge and technique.

The author's clearness of illustration and description have been most ably assisted by the many beautifully reproduced figures in the text.

Military Surgery. By D. P. PENHALLOW, S.B., M.D. (Harv.). With Introduction by SIR ALFRED KEOGH, G.C.B. Illustrated. 1916. London: Henry Frowde and Hodder and Stoughton. 15s. net.

MILITARY surgery of to-day is a great subject full of problems. Changes in treatment and administration are constantly occurring, so that it needs great diligence to keep *au courant* with what is taking place in the wide war zone. New diseases, too, are cropping up, and new conditions being added to those under which we have been accustomed to work. Hence it is not easy to write a book that shall deserve the title Military Surgery, nor do we think that the time is ripe, even now, for the attempt. The surgeon who ventures on the task ought to possess the wide practical experience of his subject that can only be gained by prolonged personal acquaintance with war wounds in all regions of the battle area; he should be acquainted with the writings of the principal authorities; and, above all, he should be well endowed with that critical faculty without which experience and knowledge are of little value.

In these respects the work under review is disappointing. The surgery in France differs widely from that seen in this country, and no book can deal properly with military surgery that does not give an adequate description of the conditions at and immediately behind the front. Dr. Penhallow fails to do this. All through, one breathes the tranquil atmosphere of the base hospital; and nowhere is one made conscious of the bustle and turmoil of the fighting zone, with its appalling casualties, fulminating complications, and necessarily hurried treatment.

In other respects also the volume is open to reproach. To some extent the shortcomings must be attributed to its relatively premature appearance. A book of this size must have been completed before the appearance of much important recent work. This is the author's misfortune; but it supports the view that the time is not yet ripe for a comprehensive work.

The book under review discloses a want of critical judgement and power of discrimination. There occurs on page 20 a passage that shows how this lack of wide experience on the part of the author might lead the reader into a grave error in practice. It runs: "Transportation is also an important factor in many wounds, as regards shock especially . . . in abdominal wounds. Such cases are best allowed to remain quiet for several hours after they have been dressed, before any attempt at transportation is made, otherwise the fatigue incident to a long, uncomfortable ride

in an ambulance or on a stretcher, or even in a hospital ship, may prove too exhausting for the patient, and the chances of his recovery will be minimized." This dictum is diametrically opposed to the practice of to-day, for the reduction in mortality among these cases has been in a large measure due to the adoption of a course exactly the opposite to the one Dr. Penhallow recommends ; the patients are hurried down to the abdominal hospital as rapidly as possible. Of all the factors making for a high mortality, loss of time is perhaps the most potent.

In another part of the same chapter is an account of a convoy of wounded arriving at " the base hospital 24 to 36 hours after they have been wounded," with " all the signs of collapse," and being given, amongst other things, " a warm bath " before being put to bed and having their dressings changed, or their fractures properly immobilized. Obviously this picture is wrong in almost every particular. Convoys of wounded rarely reach the base hospitals in England in twenty-four hours from the time the wounds were inflicted ; if they do, they certainly do not contain cases suffering from great collapse. If it is meant to be an illustration of what occurs in France, where the convoys do come in within a short time, and the men are often very collapsed and always very sleepy, the administration of the warm bath before proceeding to other measures is an entirely imaginative touch ; in the first place hospitals are not fitted with accommodation for warm baths on the scale here suggested—there are Russian vapour baths in plenty, but they are for the very slightly wounded or the convalescent ; in the second place, no medical officer would sanction their employment until all wounds had been properly attended to, and only then in rare instances. The author must be aware of this, but there is every reason for the reader of what he writes to take the opposite view.

On page 21 the performance of direct blood-transfusion for severe hæmorrhage is recommended, and is referred to again later ; it would have been well had the author devoted a little space to the discussion of this important subject ; it certainly has a field of usefulness, but there are limitations and difficulties that should be mentioned.

Tetanus does not receive the consideration that its importance merits. The whole subject is undoubtedly full of difficulties, but this does not justify the author in dismissing the important questions of localized tetanus, as well as the long delayed and the so-called 'latent' forms of the affection, in a single paragraph and a single illustrative case. The author quotes, without any hint of dissent, the following extract from a paper by Mackenzie Forbes, " It is wiser to assume that all wounded have been infected by tetanus, and that all have not been treated with a prophylactic dose of serum at the front, and for this reason should be given a dose after admission to the hospital." It is a strict rule that antitetanic serum shall be administered to every wounded man at the front, and that this fact and the number of units given shall be entered by the M.O. upon the man's tally. There can therefore be no reason for assuming that no serum has been given, except in the rare cases in which the tally has been lost or has not been filled up ; then the advice to give a dose at the base is sound, but not otherwise, except for the special reasons put forward in the recent Report of the Committee on Tetanus, which is not alluded to. The instructions for the treatment of the declared disease are not clear enough. We are told that the wound should be " cleansed, under ether if necessary," but there is no information as to the attending risks, or the precautions that should be taken to avoid them. The only doses given for the administration of antitetanic serum are from 500 to 3000 units per diem. Some reference should have been made to the massive doses that have not infrequently been given during this war. There is no mention of the intramuscular injection of the serum ; since this is perhaps the most valuable route, the omission is serious. Thrice the space and many times the detail bestowed upon the serum treatment are devoted to the exploded methods of treatment by carbolic acid and magnesium sulphate.

In the chapter dealing with the treatment of wounds in general, Dr. Penhallow devotes himself almost exclusively to the methods suitable for cases as they come into the base hospitals in this country. The treatment of wounds at the front has given rise to more discussion, and has caused our army administrators more trouble

than any other surgical question during the past two years : Dr. Penhallow dismisses it in sixteen lines.

The hypochlorous-acid and Wright's saline methods are described and praised. In the account given of Carrel's method there are omissions, and one important error, viz., that eusol is the solution employed. Those who have been to Compiègne, and know the importance there attached to the use of Dakin's solution, will agree that this is a serious misstatement. The most serious omission is the absence of any mention of the careful bacteriological examinations of the wounds that play so large a part in the method properly applied. There is a reference to this on page 81, but no description of Carrel's method is complete without it.

The well-known 'salt-pack,' so frequently and so successfully employed at certain hospitals at the Rouen base, is but vaguely described, and Captain Roberts's excellent paper on the subject appears to be unknown to Dr. Penhallow. We have been unable to find any mention of the use of Thiersch's grafts for covering granulating wounds that cannot be brought together or covered by skin flaps.

There is no reference to the vexed question of the 'flapless amputation' for gas gangrene and other infected cases. It should certainly have been discussed. On page 107, the elementary rule that all missiles in infected wounds should be removed as soon as possible, while those in non-infected wounds need not be extracted unless they cause impairment of function, pain, or irritation, is summed up by the author under eight different headings that are very confusing to the inexperienced reader.

The description and classification of wounds of joints in general is good, and follows in the main the *Memorandum* of 1915 ; but the statement on page 119, that "The result of all these conditions (i.e., wounds of joints with fracture of articular ends) is practically the same, and ankylosis is always to be expected in such cases," is too optimistic, and leaves out of view altogether those dreaded complications, septic cancellous articular osteomyelitis and septicæmia, which are the bugbear of surgeons abroad. The section on treatment begins by saying, "Any extensive operations should be reserved for the base, unless there be evidence of a frank and virulent infection." Nothing is more certain than that these joint cases should be treated at the earliest possible moment if good results are to be obtained. The highly important question of immediate partial or complete resection of the joint, in cases complicated by injury to the articular ends, is not referred to. The account of the treatment of these wounds is very hard to follow. On page 151 we are told that "the removal of the retained foreign bodeis should be reserved until all acute symptoms have subsided, unless signs of infection manifest themselves," while on the following page comes the more sound advice that "the retained foreign body should be carefully removed." Another statement to which exception must be taken is, that "conservatism should be the rule" in cases of wounds of the tarsal joints. Experience has taught those in France that there are few more hopeless cases for the employment of conservative measures.

It is said that at the front the treatment of fractures of the long bones "should resolve itself into the disinfection of the skin wounds." This is a very inadequate, and indeed misleading, statement. Very early radical treatment is so important, that special hospitals are being provided immediately behind the front where cases of fracture of the femur can be treated as early as possible and retained for any length of time thought necessary.

On page 171 is a picture of "common types of English army field splints." This does not include the almost universally used Thomas's knee-splint for fractured femur, the common types of splints employed in fractures of the humerus, and that applied in cases of wounds of the knee-joint. Liston's long outside splint is labelled Dupuytren's, whilst MacIntyre's splint is attributed to Liston. The formula of Hausner's glue is given on page 182, but there is no mention of the much cheaper and more efficient glue made according to the formula of Major M. Sinclair, R.A.M.C., to whom also should be given the credit for the principles underlying the apparatus figured on page 220, and there entitled 'Parker's suspension apparatus.'

When dealing with the treatment of fractures of the femur on page 203, the author gives no directions as to what kind of dressings should be used, nor is he at all clear

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as to what type of splint should be employed in any particular case ; both are points of the highest practical importance.

In the Introduction, Sir A. Keogh calls attention to Dr. Penhallow's use of bone-plating in these war fractures. This procedure has for good reasons been given up at the front long ago, save in very exceptional cases. In this country, plates are still used by a few surgeons in some cases of unhealed fractures, but up to the present there has been no convincing evidence that the method has much to recommend it, and it is strongly condemned by authorities whose opinion carries great weight.

The description of wounds of the head is too sketchy to be of much practical use. In the discussion on the diagnosis of a depressed fracture of the skull, for instance, the only really trustworthy method, viz., the use of a good stereoscopic skiagram, is not even mentioned. The statement that " hæmorrhage from sinuses is best controlled by packing, unless the laceration can be easily reached and sutured," seems to denote ignorance of the bad results that have so frequently followed this practice, and also of the common and very successful practice of occluding the laceration with a 'stamp' cut from the temporal muscle or fascia.

The section on wounds of the jaws is well written, but it would have been more useful had the author gone into more detail in respect of immediate suture of the large wounds so often met with, as well as in respect of the means best suited for approximating the edges of these wounds at a later date.

The chief complications of fractures of the scapula are said to be injuries to nerves and vessels (page 286). This may be so in the cases seen in this country, but the predominating complication abroad is septic cancellous osteomyelitis.

The treatment advised for hæmothorax is open to grave question. Passing by the statement that " ice applied to the chest is also an adjunct in controlling the hæmorrhage," as being rather a counsel of perfection than a method of practical treatment, in this war, we come to directions for cleansing the external wound. Most authorities are agreed that the pleural cavity is usually infected by the entry of the missile. The chief factor in the production of a hæmothorax is wrongly said to be bleeding from the chest wall. We also find it stated that aspiration of a hæmothorax " should never be undertaken before the tenth or twelfth day, as otherwise there is danger of recurrent hæmorrhage." It is well known that this danger is infinitesimal, and no one now dreams of waiting this length of time for that reason. The statement, unsupported by any authority, is made that " the aspiration of the chest should never be done in one stage, but should extend over several days. The fluid should be withdrawn slowly and only in small amounts every other day." The author then proceeds to quote from Sir J. Rose Bradford the description of paracentesis thoracis with oxygen replacement in which it is rightly stated that one of the advantages of this method is that the whole of the fluid can be drawn off at one sitting. The reader may well be excused a feeling of bewilderment. There is no mention of the bacteriological examination of the fluid withdrawn, which is so vitally important in treatment.

The section on wounds of the abdomen bears traces of having been written later than the rest of the book, and is therefore more up to date. But if the author had clearly divined the significance of what has been written on the treatment of these cases, he could not have penned the following sentence : " Those cases which have been caused by bullets and which show peritoneal symptoms, and in which there are no signs of hæmorrhage, may be treated by the expectant method, which consists essentially of rest and quiet induced by morphia, and abstention from food except for small amounts of water, until such times as adhesions will have had a chance to form and thus localize any infective process." What modern authority can be cited in favour of such a return to the bad old methods ?

We think we have quoted enough to justify our contention that this book cannot be regarded as a true guide to military surgery. It is well got up, and is profusely illustrated with good photographs and skiagrams, and there are detailed notes of a good many illustrative cases. As a record of the surgical experience of a particular surgeon at a particular base hospital it is not devoid of interest ; but it is to be regretted that the author did not choose for it a title more accurately indicative of its real scope.

SHORT NOTES ON BOOKS.

CRILE has published in lecture form, under the title of *The Kinetic Drive*,[1] an epitome, which is also an extension, of his well-known theories about the inter-relation of various nervous, cellular, and metabolic phenomena. Of its 71 pages, 21 are occupied by pictures, most of which represent microphotographs of tissue changes produced by emotion, infection, or other activating principles which convert potential into kinetic energy. References to the emotions, pain, and exhaustion associated with the war, and a remarkable case of glycosuria cured by lessening the thyroid and adrenal activities, are points of special interest.

Mansell Moullin, in a small book of 55 pages, has expounded the views which he set forth in 1912 as to *The Biology of Tumours*.[2] It is almost impossible to epitomize these views, which are founded chiefly on the idea that tumour formation is due to a reversion to asexual reproductive activity on the part of certain tissue cells. Like many other tumour theories, this view serves to obscure rather than to illuminate the problem with which it deals.

Mr. Morriston Davies is to be congratulated upon the skill with which he has re-written the book (published first in 1861) on *Minor Surgery and Bandaging*,[3] by Christopher Heath, and since then re-edited by Bilton Pollard. The present is the sixteenth edition, and its chief addition since the last is that of a chapter on military surgery, which gives a brief mention of a few selected points in the treatment of gunshot wounds.

MM. Masson et Cie, Paris, have been most fortunate in the selection of subjects and authors in their series of small handbooks entitled *Collection de Précis de Médecine et de Chirurgie de Guerre*,[4] and also in the period at which these have made their appearance: a period when enough experience has been gained of modern military surgery to justify its publication, and one when the need for precise teaching is being experienced on all sides. We greatly regret that the limits of our space prevent us from giving these most excellent little books more than a very brief notice, but we can cordially invite every surgeon to provide himself with all those which deal with the surgical aspects of the war.

Professor Leriche, of Lyons, contributes two volumes on the subject of *Fractures*. The first is devoted to those involving the joints, the second to those of the shafts of the long bones. The teaching of the great Lyons surgeon Ollier dominates all that the author lays down. In the treatment of joint fractures, early and thorough exposure of the lesion, removal of fragments of bone, and preservation of the ligaments, tendons, and capsule, are the main principles to be observed, and regarding this there can be but little difference of opinion. It is otherwise with the treatment of fractures of the shafts, in which the author advocates the routine removal of fragments of bone, which he terms sequestra (thereby, we venture to think, begging the whole question). However, it is good for us to have the opposite of our own beliefs advocated, so that we may re-examine our own practice. Apart from what we regard as a quite wrong wholesale removal of bone fragments at the earliest possible date, the book contains much that is useful in the practical treatment of gunshot fractures. The use of plaster-of-Paris is much more prominent than we would have it; but a fair presentation is given of the most useful types of fracture apparatus.

Professor Broca, of Paris, writes on the *Bone and Joint Sequelæ following Gunshot Injuries*. He deals with vicious union, excess of callus, pseudo-arthrosis, chronic osteomyelitis, and ankylosis of joints. The description of these various conditions

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[1] *The Kinetic Drive*. (W. B. Saunders Co.) 8/6 net.
[2] *The Biology of Tumours*. (H. K. Lewis & Co. Ltd.) 2/6 net.
[3] *Minor Surgery and Bandaging*. (J. & A. Churchill.) 8/6 net.
[4] *Collection de Précis de Médecine et de Chirurgie de Guerre*. (Masson et Cie, Paris.) 4 fr. each.

and their results is very good, but there is a great deficiency in exact and detailed direction as to surgical intervention, such as that of bone-grafting, and the operative treatment of deformities.

Professor Broca and the orthopædic surgeon Ducroquet contribute a most clear and practical account of *Artificial Limbs and the Principles of their Construction*. This is the outcome of the experience gained during the present war in the "Fédération des Mutilés." The diagrams illustrating the different types of apparatus are very clear and useful, and we could wish for a similar book in English describing the corresponding apparatus which is being made for our own wounded. We should like a little more information as to the actual results obtained by the limbs described, especially as to whether the complicated and expensive mechanism of artificial feet and hands is found of practical value. For this information, however, we must wait for a further period.

Professor Ombrédanne and M. Ledoux-Lebard have written a most valuable treatise of 349 pages, illustrated by 225 figures and 8 full-page plates, on the subject of *The Localization and Extraction of Projectiles*. It is notable for its completeness and accuracy, and its evenly balanced surgical opinions. First there is a simple description and explanation of the *x*-ray apparatus suitable for military work. This is followed by a section dealing with the detection and exact localization of foreign bodies, which perhaps errs a little on the side of complexity. The final section deals with the technique of extraction in different regions of the body, concluding with a short description of various methods—e.g., that of the electro-magnet, telephone probe, etc.—which are rightly relegated to a secondary place. We think that this is the most complete and practical treatise of its kind that has yet appeared, and this result is due in large measure to the co-operation of a practical surgeon with a radiologist.

Madame Athanassio-Benisty, a resident at the famous hospital of Salpetriere, has written a concise account of the *Clinical Forms of Nerve Injuries*, which is prefaced by Professor Pierre Marie. Within the scope of 235 pages, illustrated by 81 figures in the text and 7 plates, the authoress has given a full and practical account of the anatomy, pathology, and symptoms of peripheral nerve injuries. From a neurologist's point of view it is very clear and complete; but it is not a surgical treatise, and requires to be supplemented by a description of operative methods and orthopædic appliances.

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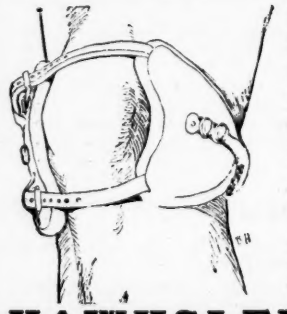

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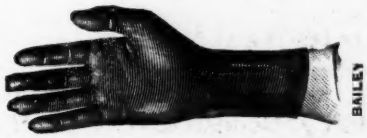

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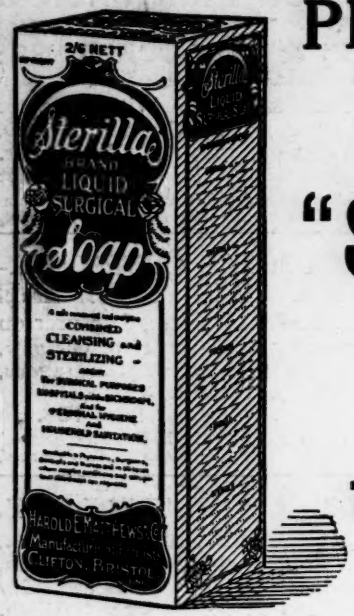

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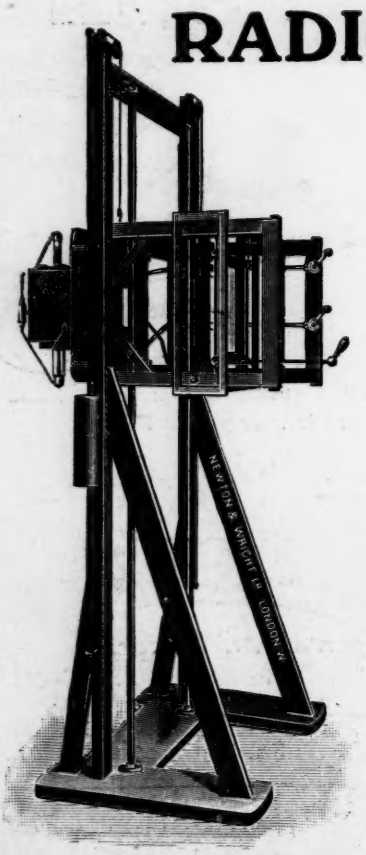

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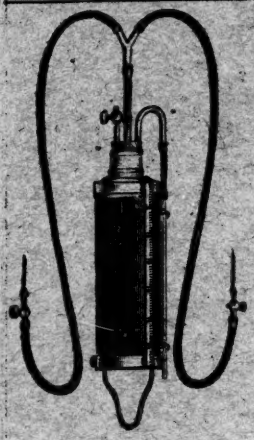

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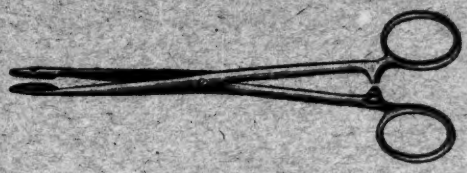

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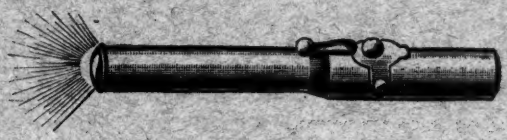

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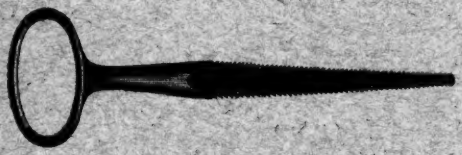

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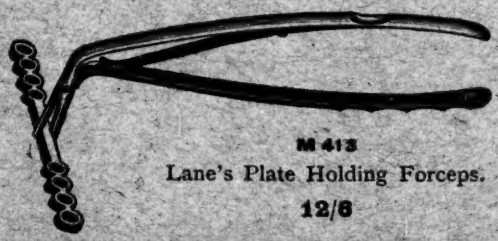

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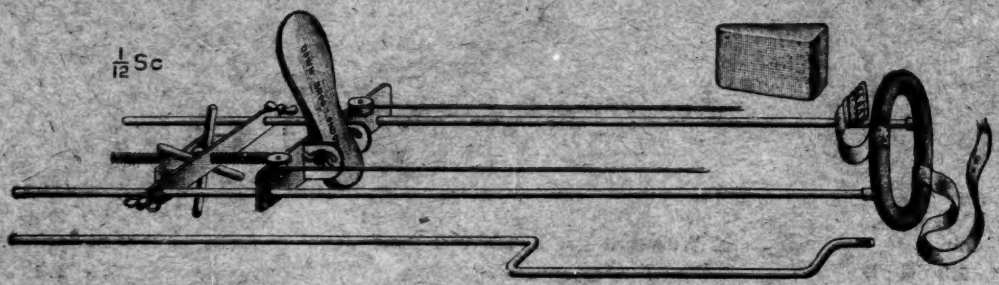

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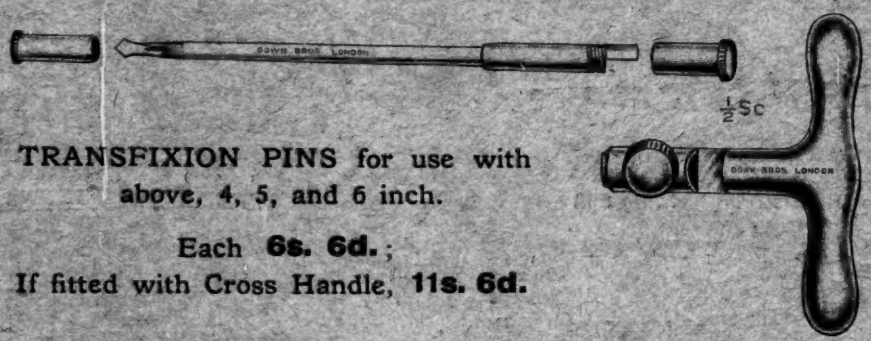

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